TOOTH SIZE AND OCCLUSION IN TWINS

BY

ANDERS LUNDSTRÖM

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ANDERS LUNDSTRÖM

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PREFACE.

The aim of the present work is to analyse on twins the importance of genetic and non-genetic factors especially for the tooth-size, the tooth-space in the dental arches and the occlusion between the jaws. An investigation of this kind is of interest especially in regard to the etiology of malocclusion. The more severe malocclusions are too infrequent to appear among these cases and the work therefore deals with the variability in cases with more or less normal occlusion. The number of twin-pairs investigated is 100 identical and 102 fraternal pairs, mainly from Stockholm and the surrounding area.

This work owes its inception to Professor *Gunnar Dahlberg,* head of the Swedish State Institute of Race Biology, who has also granted me the privilege of carrying out the investigations at the Institute. For this, and for the invaluable advice and help, that Professor Dahlberg has generously given during the investigation, I am deeply indebted.

Ph. D. *Yngve Norinder* has given me many twinaddresses, for which I am most thankful. I beg also to acknowledge my indebtedness to others, teachers and collegues, who have helped me in procuring twins for the investigations.

To the staff of the Institute, and especially Miss *Saga Neander,* who has carried out the statistical work, I want to express my sincere thanks for all assistance and qualified help.

To Mrs. *Else Larsen* I wish to express my gratitude for the care taken, and the interest shown in translating the work into English.

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Stockholm, March 1948.

Anders Lundström.

CHAPTER I.

REVIEW OF THE LITERATURE

Since the time of *Galton,* twins have been used for deciding the role of "nature and nurture". However, they cannot be used for deciding which environmental factors and, especially, which hereditary factors play a part. Therefore it seems suitable not to limit the survey of literature only to twin investigations but to go into the research made in the whole field as regards the etiology of malocclusion in order to get a complete background to this investigation.

To which extent environmental factors *in utero* might produce such changes is hardly analysed, and of course, the problem is very difficult to tackle.

Some examinations are to be found dealing with the consequences of that compression which takes place during *delivery. Dahlberg* (1926) has shown through examination of twins at an average age of 15½ years that this compression at birth produces not only an average extention of the head amounting to 1.25 ± 0.40 mm. but also an average extention of the face amounting to 1.08 ± 0.38 mm. This examination is of importance because it has shown that the usual trauma which a delivery implies may affect the structure of the face permanently. It is then conceivable that an especially difficult delivery would probably produce more obvious changes.

Hofbauer (1943) examined 500 newly born children in order to determine the effect of occuring traumatic action on the occlusion in connection with delivery. From 125 children, models of the jaws were reproduced and on all 500, measurements were taken of the sagittal occlusion at the frontal part of the gum-pads. The cases were divided

into four groups according to the type of delivery: 1) normal delivery, 2) delivery with forceps, 3) delivery with the help of the Veil-Smellies grip (resulting in a pulling of the jaws), 4) delivery by means of a caesarean cut. Any connection between the occlusion and the type of delivery or different positions of the fetus could not be shown. Naturally this does not exclude the possibility that damage during delivery, in rare cases might cause more or less lasting changes in the occlusion.

Postnatal factors that have been connected with the origin of malocclusion are of mechanical type, tooth extractions, factors connected with the function and factors which depend on the type of food.

As regard the mechanical factors it is obvious that, in order to produce an effect, they ought to give a slow and constant pressure. That such a pressure is of great consequence is known by the effect of orthodontic treatment. It is therefore not impossible that *fingersucking*, for example, has a certain effect. This is also the general conception in handbooks and other literature. The opinions which have been advanced to support this theory are, however, not so convincing at least as regards permanent changes. As the sucking of fingers is a very common habit among children one must of course, in order to prove something, confirm that the habit has continued for a comparatively long time, or has been exceptionally intensive with children who suffer from malocclusion than with those who do not. It is obvious that it is very difficult to obtain a measurement of the intensity of thumbsucking, and equally difficult to obtain a definite specification of time. One difficulty which has only been touched upon in literature is the unreliability of the information obtained, because parents of children with certain malocclusions are probably more inclined to give information about the occurrence of fingersucking than parents of children with normal occlusion or with other anomalies. Consequently it can be questioned whether the examinations which have

been carried out several years after the termination of the sucking of fingers are entirely reliable.

Many writers have tried to illustrate the danger to the jaws caused by fingersucking through demonstrations of comparatively few cases (e. g. *Campbell* 1870, *Chandler* 1878, *Watkens* 1884, *Heckard* 1903, *Ambler* 1904, *Le Roy Johnson* 1915, *Haas* 1937, *Jutkowitz* 1941). Material of this kind has naturally slight value as a proof, as the cases published may be selected among the more extreme cases.

Individual cases which show that any definite connection between the habit of sucking and the jaws does not exist, have been described by *Talbot* (1890) and *Kingsley* (1892). These writers found cases which, in spite of the fact that fingersucking took place until a relatively late age (7—9 years), showed normal occlusion, and also cases with anomalies which generally are considered to be connected with thumbsucking without any such habit ever having taken place.

More systematic examinations have also been carried out (table 1).

Lewis and *Kjellgren* found that with young children (mainly deciduous dentitions) the differences in the frequency of deviation of the front teeth between cases with and without fingersucking were 80 to 85 per cent. These differences are so great that even when due allowance is made for the possibility that misleading information from parents has caused differences greater than those found in reality, the effect of fingersucking on the position of the deciduous front teeth can be considered as proved.

Whether postnormal occlusion of the lower molars may arise as a result of fingersucking cannot be considered as sufficiently ascertained. *Hellman*'s examination, it is true, gives a significant higher frequency (the difference = 22.3 $\pm$6.2 %) of postnormal occlusion in the cases of fingersucking than in the cases which were not selected as regards this habit. The material is, however, very heterogenous as to age (between 3 and 15 years), which fact,

Table 1. **Fingersucking and malocclusion according to different authors.**

Author	Character of cases	No. of cases	Age	Frequency of malocclusions: Deviations of front-teeth	Frequency of malocclusions: Postnormal occlusion at molars
Hellman (1922)	Cases with malocclusion and with sucking habits	90[1]	3—13		60.0 %
	Cases with malocclusion not selected with respect to sucking habits	191	3—13		37.7 %
Lewis (1931)	Thumbsuckers	30	1—9	80.0 %	
	Without thumbsucking	129	1—9	0.0 %	
Swineheart (1938)	Cases with malocclusion and with fingersucking	38	3—14	89.4 %	42.0 %
Kjellgren (1939)	Fingersuckers[2]	167	1—6	87.0 %	
	Without fingersucking[3]	1000	1—6	1.6 %	
Sillman (1940)	Thumbsuckers	13	0–3	53.8 %	15.4 %
	Cases without fixed habits	18	0—3	61.1 %	11.1 %

[1] Out of which 72 fingersuckers, 23 »comfort»-suckers and 7 cases with other habits.

[2] = fingersucking after 1 year.

[3] Approximate figures.

together with the uncertain method of examination and the unreliability of the information obtained may very well explain the result.

Observations carried out as to changes after the termination of fingersucking show that a relatively speedy spontaneous correction usually is taking place. *Lewis* (1930) found in 24 cases of thumbsucking with malocclusion a spontaneous correction in 9 cases, out of which 8 ceased thumbsucking before 5 years of age and 1 after. In the remaining 15 cases which were not corrected spontane-

ously the habit ceased in 5 cases at the age of 5 years, and in 10 cases after that age. The majority of the cases seem only to have been followed up to 5 or 6 years of age, and Lewis emphazises that a longer time of observation would be necessary to decide the final result of the latter cases. *Kjellgren* had 26 cases under observation after the termination of the habit. Out of these 18 cases showed spontaneous correction and 5 cases relatively good improvement and 2 cases a slight improvement. Only 1 case remained unchanged but a non-terminated habit of lipbiting existed here. In 7 cases the correction had taken place in less than 6 months, in 9 cases within a period between 6 months and one year, in 1 case after 2 years and another after 3 years. *Ritter* (1944) has demonstrated a pair of identical twins (both thumbsuckers), one of whom ceased the habit at the time of the eruption of permanent incisors, and the other not until 9 years and 7 months of age. At this age, the first one showed normal occlusion and the other an open bite frontally. After approximately 2 years however, the occlusion of the latter was practically the same as that of the other.

The investigations as to the connection between fingersucking and the occlusion have, as a rule, been carried out during the age of deciduous dentition. A demonstration of the effect on the position of the deciduous teeth is, however, of relatively little interest, especially as it is known that the habit of fingersucking, in exceptional cases only, continues after the eruption of the permanent teeth. With due regard to this, and to the reported spontaneous correction after the termination of the habit it seems probable that fingersucking as a cause of permanent malocclusion is a factor of relatively little importance.

Besides fingersucking, other habits involving pressure on the jaws have also been given as reasons for anomalies of the tooth position. Certain sleeping habits with hands, arms and other things against the jaws have been specially mentioned in connection with this. *Stallard* (1923, 1925,

1930) has carried out observations on approximately 300 children during their sleep and reported that 20 % of the children had sleeping habits which could be connected with their malocclusions (saddle-formed upper jaw, postnormal and prenormal occlusion etc.). Any specification as to the frequency of the different anomalies in cases with and without sleeping habits have, however, not been given. Because of this fact one cannot exclude the possibility of a subjective selection. The stated hypothesis seems not very probable.

Crosby (1929) tried to show the significance of sleeping habits and so-called "propping habits", i. e. habits of leaning the head against the hand so that a pressure occurs on the side of the chin. This hypothesis is based on five selected cases but these are not sufficient as a proof that such habits have any effect on the occlusion.

Premature loss of deciduous teeth has been considered of great importance by many writers as the causative factor of malocclusion without, however, any decisive proof being produced.

Pfänder (1930) was the first investigator who made more extensive examinations as to extractions of deciduous teeth and their connection with the tooth position. He registered the lost deciduous teeth in 1600 children aged 6—12 years, and the tooth position using eye-measurements. For 30 cases which seemed to be particularly instructive, plaster casts of the jaws were produced by means of which comparisons were made between the left and right side, and between the upper and lower jaw.

The estimation of Pfänder's results is made difficult because of the indistinct definition of the diagnoses. The cases from which models were taken represent a selection, and therefore it cannot be excluded that these are hereditary anomalies which have been associated coincidentally with extractions. Any examinations of the frequency in a control-group was not made, which is the reason why

Pfänder's work does not give a contribution worth mentioning to the solution of the given question.

Pringle (1937) and *Seipel* (1946) have shown that a certain contraction of the spaces after extractions takes place, especially after deciduous molars. Pringle showed this contraction in the case of children between 7 and 8 years of age, while Seipel showed the same with children between 3 and 7 years. To which extent this contraction involves anomalies in the dentition, or whether the lack of space produced in this way is compensated through later growth, evades our judgement.

Pringle (1937 and 1939) examined 850 anomaly-cases aged 7—8 years as to the effect of premature loss of lower deciduous teeth on the overbite (table 2).

Table 2. **Overbite in cases with normal mesio-distal occlusion at M_1 at the age of 7—8 years (according to Pringle 1937).**

Group	No. of cases	More than 1/3 overbite
No loss in the lower jaw.....	29	31 %
Loss on one side of lower jaw	21	57 %
Loss on two sides of lower jaw.....	60	82 %

The difference in the frequency of deep overbite between cases with losses on both sides in the lower jaw, and cases without any loss is 51±9.9 % and is therefore significant. As the observations ceased at the age of 7—9 years it was not possible to decide whether this displacement became permanent. Because of this and also of the vague method used (measuring the degree of overbite by eye), the result cannot be considered as sufficiently proved.

Ungar (1938) examined 292 cases between 3 and 14 years of age. Each case was examined yearly, and for some cases the development was followed up to the age of 14 years. The majority had, however, not been examined after 7—8 years of age. At what age the teeth were lost was not registered. In cases with anomalies of the tooth position the

frequency of the loss of teeth was 28.5 %, and in the remaining cases 13 %. The difference is 15.5±4.6 % which is significant. But nevertheless the result cannot be considered as a proof because with subjective limits there is always the risk of systematic errors when diagnosing. Besides this, the time of observation is too short to prove whether those malocclusions observed are permanent. As regards the circumstances mentioned neither Unger's examinations can be said to give any decisive results.

Schachter (1943) examined the toothposition of 130 cases between 11—16 years of age (average age being 12.2 years) with premature losses. A loss of the first deciduous molar not later than 8 years and not later than 9 years for the 2nd deciduous molar was registered as premature. Out of these 130 cases, 70 (≙ 53.8 %) showed a normal eruption of all teeth. Out of the 60 remaining cases with anomalies 20 were classified as due to insufficient growth of the jaws, whereas the anomalies in 34 cases were supposed to depend upon the loss of deciduous teeth only. In 6 cases uncertainty of the causes existed. The decision as to whether insufficient growth existed, or whether the anomaly had been caused by premature losses was not based on any more detailed objective reasons. It is difficult to understand how such a differentiation could have been made, considering that it is not proved if there are any anomalies that occur as a result of premature losses only.

Schachter also examined 50 cases which had extensive losses (4—8 deciduous molars) between 2 and 6 years of age (average age 5.3 years). The cases were examined at an age of 10—16 years. Only 8 cases (= 16 %) showed normal eruption of all teeth, and all of them had lost all their deciduous molars. The difference between the frequency of normal cases in this group and the former is 37.8±6.8 % which is significant. However, because of the uncertainty of measurements by eye neither this result can be considered as a proof. Here again, observations should have lasted longer. It is not known how many of the cases

were observed only between 10 and 13 years of age, which age must be considered insufficient in order to determine which anomalies will become permanent.

A. Lundström (1944) examined 118 cases at 13 years of age as to the connection between the premature loss of deciduous teeth during school age (after 7 years) and the tooth position. The losses were divided into earlier (at 7 and 8 years of age) and later periods (at 9 years of age for the first, and at 9 and 10 years for the second deciduous molar). The tooth position was examined by measurements as regards the occurrence of crowding and the size of the over-bite. Significant differences as to the frequency of crowding between cases with, and without premature loss of deciduous teeth did not exist for the whole dental arch, and on one side only in the case of certain sections of the dental arches. Therefore the examinations did not give any cause to believe that premature losses during school age would produce crowding. Nor could any connection between premature losses in the lower jaws and the overbite be proved. A most probable connection, according to statistical estimation, was obtained between the vertical overbite and lack of space for the premolars in the lower jaw. It therefore appears probable that at least very early losses of deciduous teeth in the lower jaw leads to a slight increase of the over-bite. (The mean difference was 0.9 mm between cases without and cases with crowding of the second premolar in the lower jaw.)

Seipel (1947) found in cases of 10—14 years of age significant differences for space-values on the left and right side in cases with one-sided extractions of the deciduous molars at 3—5 years of age, with less space on the extraction-side (the mean difference = 1.9 ± 0.30 mm.). One of Seipel's cases is particularly interesting as it shows how, after a premature loss of the second upper deciduous molar, in the beginning a strong contraction of the space occurred so that at the age of 9 years and 10 months the first premolar and the first molar were in contact with

each other. However, associated with the eruption of the second permanent premolar a reversible migration took place, thus this tooth at 13 years and 6 months had a completely normal position in the dental arch. This illustrates clearly that the effect of the loss of deciduous molars can not be estimated until after the time of eruption for the premolars, or in other words, generally not until after the age of 12—13 years.

The question as to the consequences of *extraction of permanent teeth* is to a certain extent beyond the subject of this work. It is out of the question therefore, to give any detailed report of the very extensive literature and work on this subject. The discussion in this question has mainly been concerned with the therapeutic effect of different extractions on crowdings, and many writers have, in this connection, shown how extractions cause migrations of the teeth on both sides of the spaces, with a more or less favourable effect on the crowded teeth according to the distance between the extraction-space and the position of the malposed teeth. (Compare e. g. *Sternfeld* 1899, *Förberg* 1901, *Kunert* 1903, 1909, 1916, *Riesenfeld* 1908, *Greve* 1915, *Brodtbeck* 1921, *Sippy* 1927, 1928, *Lipschitz* 1927, *Philips* 1927, *Levy-Davidsohn* 1933, *Salzmann* 1937, 1938, 1939, *Baume* 1939, 1940, *Seipel* 1946, *Björk* 1947.) Salzmann, Baume, Seipel and Björk have made more systematic studies of the effect of extractions, and these writers have shown how spaces after extracted 6-years molars tend to contract during the development of the jaws, and that this contraction takes place more quickly in the upper than in the lower jaw.

Baume has, by means of measurements, been able to show that this contraction mainly takes place from behind and to a smaller degree from infront when measuring in relation to prostion and infradental point.

In the literature dealing with the effect of extractions of 6-years molars it is maintained that such losses should lead to an increased over-bite, which fact has been repeated

so often that many writers consider it as perfectly proved. It does not seem, however, to be supported by any other objective material than descriptions of individual cases which have little value as evidence. Baume got no such result as 10 of his cases with extractions of all 6-years molars showed decreased overbite, while an increased overbite was observed only in 2 cases.

Seipel found that the frequency of rotated teeth was greater in cases with than in cases without extractions, especially when occuring in the lower jaw (the difference = 13.9±2.7 %). Particularly great differences were found for the second premolar in the lower jaw, and the second molar in the upper jaw.

Seipel measured the distance between porion and the occlusion, and he found that extraction cases at 21 years of age showed a shorter distance than cases without extractions. Thus, the mean difference between cases without and with missing teeth in the distance between porion and the medial incisor of the upper jaw, was in women 4.1±1.3 mm. where bilateral extractions of M_1 in the same jaw existed, and 3.0±1.28 mm. in cases of unilateral extractions. A corresponding difference was found in the distance between porion and the distal contact of P_2, this was 4.9±0.58 mm. on the side of extraction.

Björk (1947) has made measurements on lateral X-ray pictures of the head, and among other things determined the differences between cases without and with losses of the teeth in children of 12 years of age (322 boys, 26.4 per cent with losses), and in adults of 20—21 years of age (281 conscripts, 56.9 per cent with losses). He found a shorter upper dental arch (from the first molar to the medial incisor) in cases with losses than in cases without losses in both age groups (diff. = —1.80±0.43 mm. and —1.36±0.46 mm. respectively). The same difference was significant in the lower jaw with the boys (= —1.07±0.35 mm.). Conscripts with missing teeth were found to have less protruding incisors in both jaws than those without

missing teeth (the difference in the distance from an X-ray point on the posterior border of the condyle of the lower jaw to the incisal edges being —2.52±0.61 mm. in the upper and —1.98±0.65 mm. in the lower jaw).

In medical and odontological literature much space has been devoted to the effect of *hindered nose-breathing* on the development of the jaws. At an early stage different writers showed the connection between a narrowly built face and nose and a narrow dental arch of the upper jaw (e. g. *Bentzen* 1903, *Bloch* 1903, *Buser* 1904, *Nordlund* 1918). A connection between this type of face and mouth-breathing (mainly associated with adenoids) has also been shown.

Bloch tried to examine the causal significance of mouth breathing on the form and height of the palatal vault by an index showing the relationship in per cent between the height and the breadth of the palate in cases of mouth- and nosebreathers among 158 broad faced and 385 narrow faced individuals.

Inasmuch as mouthbreathers showed relatively higher and/or narrower palatal vaults than nosebreathers with both types of faces, Bloch considered it proved that mouth-breathing is the direct cause of this form of the palatal vault. His result is, however, in itself natural. It is obvious that with narrow and tight air passages, the palatal vault too is generally high and narrow irrespective of the fact that the face also is of the same type. It is then impossible to decide whether the narrow and high palatal vault and the nose is the primary factor or, whether mouthbreathing is.

Buser tried to determine the significance of mouthbreathing by determining the frequency of mouthbreathing in relatively broad faced individuals with broad nostrils but with a narrow dental arch, as in these cases the latter could not be explained as a symptom in connection with the narrow type of face. Out of 27 men only 1 was found, and

out of 26 women only 3 were found to be pure mouth-breathers.

The condition of the occlusion with one, or few selected cases with mouthbreathing has been described by several writers such as *Kingsley* (1892), *Turner* (1913), *Northcroft* (1910), *Wright* (1922), *Bull* (1924) and *Lourie* (1928). These descriptions show that any definite connection does not exist between mouthbreathing and any malocclusion.

More systematic examinations have also been made by some writers. *Layton* (1914) examined 25 children who had been breathing through their mouths for at least six months before reaching 9 years of age. Out of these cases, only one showed such conditions of malocclusion as are usually stated as being typical with mouthbreathing. 8 cases were completely normal whilst the remaining cases showed different types and degrees of malocclusion of the teeth.

Howard (1932) examined 500 cases with augmented tonsils for the control of the often presented hypothesis about the connection between this condition, and prenormal occlusion of the lower jaw. The improbability of this hypothesis appeared from the fact that only 4.2 per cent showed this anomaly. Among 159 mouthbreathers, 59.1 per cent had normal occlusion.

Marcus (1932) has prepared 2988 specifications from journals of odontological consultation in Bonn as regards the conditions of the tonsils of the throat, and the occurrence of malocclusion in children. He found a particular high frequency of over-developed tonsils in cases of mandibular prognathism, and the difference between this group and the cases without anomalies was significant. Other anomalies, apart from close-bites, also showed a high frequency of difficult tonsils as compared to the normal group. It is, however, impossible to estimate the value of these observations because one cannot eliminate the possibility that the results depend upon the conception of those who had written the journals, leading to a higher frequency of the diagnosis "over-developed tonsils" in cases

with such anomalies as are generally connected with that diagnosis.

Balyeat and *Bowen* (1934) examined the frequency of V-formed palatal vaults of 500 children, out of which a 100 were unable to breathe through the nose as a result of chronic nasal allergy; 100 children from a hospital for disabled persons; 100 white; 100 Indian-children and 100 Negro-children. The V-formed palatal vault appeared in these groups in 24, 5, 7, 4, and 4 cases respectively. As the examination was made by means of eye measurement, no other conclusion can be drawn except that a more intimate connection between mouthbreathing and V-formed palatal vault does not exist.

Johnson (1936) found that out of 10 cases with high palatal vaults and 10 cases of Angles class II, division 1, each group had only 3 cases with a tendency towards mouth-breathing (alternately mouth- and nosebreathing).

Examinations made hitherto in this way, seem to justify the conclusion that hindered nosebreathing is not the direct cause of certain definite malocclusions. The connection between mouthbreathing and a relatively long and narrow dental arch in the upper jaw is most simply explained thus, namely, that these characteristics are different expressions of a generally narrow type of face.

In odontological literature one often comes across the statement, that the high frequency of malocclusion nowadays should depend upon the fact that the too easily chewed food does not give the jaws the full *function* which is necessary for their normal development. It is presumed that in the earlier phases of the history of mankind, characterised by a more "natural" way of living, man should on the whole have been free from at least the more serious types of malocclusions. The author has in an earlier work (1946) related previous examinations as to the size of the jaws and the frequency of malocclusions during the different epochs of time (*Keith* 1924, *Selmer-Olsen* 1936, *Smyth* 1939, and *Mellquist* and *Sandberg* 1939), and also

made examinations on material from the Stone Age, the Middle Ages and of the present time in Sweden without, however, having been able to find any decisive proof as to the questioned changes. Examinations of this type are, however, not so yielding from an etiological point of view. Even if continued examinations should give reason to believe that anomalies are more usual in the present time, one cannot conclude from this that it is the environmental factors which are decisive. Breaking of isolation (*Dahlberg* 1943) is also a conceivable decisive factor.

Writers have been especially interested in the significance of the *attrition* to the sagittal relationship of the jaws, and they considered themselves able to trace the connection between strong attrition and the displacement of the lower jaw forward, with a tendency towards edge-to-edge bite. (*Campbell* 1925, *Friel* 1927, *Périer* 1931—32, 1935, *Schwarz* 1936, *Selmer-Olsen* 1937, *Smyth* 1935, *Hilming* and *Pedersen* 1940, *A. Lundström* 1946). As a support to this conception it has been alleged that, 1) edge-to-edge bite is a more usual phenomenon with primitive people having strong attrition, 2) even with these people a certain overbite is typical of children who have not as yet had time to wear their teeth down to a degree worth mentioning. The first circumstance can hardly serve as a proof for the maintained connection as one can also consider the difference in races as a decisive factor. The size of the difference between children (7—19 years) and adults (> 20 years) as to the frequency of edge-to-edge bite parallel to gradual progressive attrition is, according to Hilming and Pedersens material of Eskimos, clearly significant (56.5±7.3 %). This is also in good accordance with the fact that from a theoretical point of view, a minor displacement of the lower jaw forward in connection with a wearing-down of the occlusal surfaces of the teeth is probable. (*Selmer-Olsen* 1937, *A. Lundström* 1946). Direct examinations are not found as to whether an insufficient attrition of the deciduous dentition could prevent the lower jaw from

growing forward, and thereby result in an uncertain adjustment of the 6-years molars, predisposing for a development of postnormal occlusion. It seems, however, improbable that this factor can have any significance as being the origin of more serious malocclusions (cf. *Baume,* 1943).

Experimental examinations on animals in order to determine the significance of the function for the development of the jaws were carried out by *Walkhoff* (1910), *Anthony* (1913 according to Brash), *Pietkiewicz* (according to Franke), *L. W. Baker* (1911, 1922) and *Landsberger* (1912). By unilateral cutting of m. temporalis or by means of extensive extractions they obtained more or less clear asymmetries of the jaws, and the writers see in this fact a proof of the significance of the jaws' function. Apart from the possibilities of irrelevant damages to the supplying blood vessels during operations, the differences in the functioning between left and right side of these jaws are naturally far greater than the differences caused by the decreased functioning of the jaws through the change to the more easily chewed food of our time compared to that of earlier times. It is therefore scarcely possible to use the results obtained in this way in the study of the etiology of malocclusion in human beings.

The significance of lack of suitable food, and especially *lack of vitamins,* for the growth of the jaws has been the cause of much controversy in odontological literature. Rickets especially was held responsible for the origin of certain serious malocclusions such as the saddle-formed dental arch of the upper jaw and open bite. From a practical point of view this question is, however, of minor significance because rickets, which was earlier a common disease, has nowadays almost disappeared, at least serious cases are rather scarce. Malocclusions, however, still exist and could not therefore essentially be dependent on rickets.

Hatfield (1919) has examined 15 children taken from a hospital for disabled children suffering from serious symptoms of rickets. Models of the jaws were taken of all the

children. None of the cases had such formed jaws as are generally considered a characteristic of rickets, and instead of V-formed dental arches with high palatal vaults, dental arches which seemed to lay safely within the limits of the normal were found.

Franke (1921) examined 150 cases of malocclusion from a laryngological clinic and out of these 17 had had rickets, 10 of which showed malocclusions generally connected with rickets. In the remaining 133 cases there were, however, 50 more cases with similar malocclusions. Because of this reason, and the fact that 15 skeletons with signs of having suffered from serious rickets did not show abnormally high palatal vaults, or according to literature, other typical ricket-like malformation of the jaws, Franke rejects the hypothesis that a connection exists between rickets and certain malocclusions.

Friel (1922) examined the tooth position of 520 children between 6 months and 14 years of age. They belonged to the working classes in Vienna and had been given very defective diet from a quantitative, as well as a qualitative point of view for a long period of time during and after the first World War. This was especially the case as regards fat soluble vitamins. In spite of the fact that rickets was a very common disease not one single case was found with that pronounced type of malocclusion, which generally is stated in literature as being typical of rickets. Some cases with open bite were found, but the anomaly was only moderate. Nor could Friel find that other malocclusions which could be considered as signs of insufficient development of the jaws were more usual in Vienna than in England, except what Friel estimated as local effects of the premature loss of deciduous teeth. According to Friel the diagnosis were subjective, and any exact comparisons could not therefore be made. Friels examination seems to show that the effect of malnutrition on the jaws is not as great as many writers suppose.

Korkhaus (1931) has given a report of 62 cases with

open bite and he divides them into three groups consisting of: 1) 12 cases with true open bite, 2) 37 cases with open bite caused by thumb-sucking out of which 11 were without and 26 with sagittal deviation, and 3) 13 cases with open bite connected with crowdings. In group 1, 11 cases showed hypoplasia of the enamel on the 6-years molars and the front teeth, and out of these 8 showed extremely narrow dental arches, and in 8 cases postnormal occlusion was found. Apart from this, the cases were characterised by a flattening out of the angle of the lower jaw, the angle ranging from 135° to 145° while the normal values are stated to lie within 124° and 128°. Linguoversion of the front teeth of the lower jaw was found in 6 cases. Because of the combination of hypoplasia and other existing similar traits of anomaly, Korkhaus considers that rickets causes deformities of this type on the jaws. The subjective selection of the so-called true open bite, and the lack of information as to how the normal variation has been determined for the size of the angle of the lower jaws, seem, however, to make this conception untenable.

Kirsch and *Rosenbaum* (1932) have examined the connection between rickets and the jaws by comparing 3 groups of children, namely 1) a control-group consisting of 20 children without any traceable signs of rickets, 2) a group consisting of 8 children where a one-time existence of rickets was uncertain, and 3) a group consisting of 28 children who had suffered seriously from rickets and had been treated for this disease. V-formed upper jaw was only found in one case, and a high and narrow palatal vault in 4 cases belonging to the third group. Open bite was found in 2 cases, one of which had had rickets and another whose case was doubtful. An insufficient development of the upper jaws with crowding was found within all 3 groups, 1, 2, and 2 cases respectively. Curved-in molars of the lower jaws were found in 3 cases in the second group and 6 cases in the third group, while crowding in the lower jaws was found within all groups, 1, 3, and 6 cases respectively.

Kirsch's and Rosenbaum's examination seems to show that even where clear signs of previous attacks of rickets appear, malocclusions seldom occur. Any comparison between the different groups as regards the frequency of malocclusions cannot be made because of the insufficient number of cases, and because of the unreliable method of examination used.

Shelling and *Anderson* (1936) have examined 126 cases with rickets and 150 cases which were treated profylactically with viosterol for rickets. The cases with rickets were mainly coloured people (119 cases), while the control-material consisted mainly of white people (108 cases). These dissimilarities as to the combination of the material makes it naturally difficult to judge the result. Besides this, the differencies in the frequency of malocclusions are relatively small, and the diagnosis has been made only by means of subjective methods. It is, therefore, impossible to draw any conclusions as to the differences of frequency found.

Experiments on animals to establish the significance of vitamins on the development of the jaws have also been carried out.

M. Mellanby (according to Brash) has made a report of her experiments on puppies which were bred on food lacking in vitamin D. Out of 35 puppies fed on such food, 29 showed anomalous tooth position, 3 with only small anomalies, and 3 with normal tooth position. Out of 5 puppies, fed on food with only a slight deficiency in vitamins, 4 had insignificant anomalous tooth position, 1 had a normal tooth position while 4 puppies out of the 19 fed on food rich in vitamins showed insignificant anomalies, and 15 normal tooth position. Malocclusions occurred especially in the incisors of the lower jaws. The difference between the two groups, i. e. the group brought up on food deficient in vitamins, and the group brought up on food rich in vitamins seemes to be so great that it proves the significance of vitamin D for the development and the growth

of the jaws. It must, however, be emphasized that the degree of the lack in vitamins obtained in an experimental way becomes essentially stronger than the degree one has to reckon with in the case of human beings. Consequently animals used for such experiments suffer so much in health, and have such slight possibilities to develop that the jaws also are included in the disturbance of growth. Under no circumstances do these types of experiments entitle anybody to draw any conclusions that malocclusions of this type should generally depend upon deficiency in vitamins.

The same point of view could be maintained as to the results achieved by *Howe* (1923, 1927) on his experiments with apes, and the experiments of *Schultz* (1933) on rats with food causing rickets or scurvy.

When considering the significance of *heredity* as being the cause of the origin of malocclusions, *experiments* carried out *on animals* are of interest.

Gaspar (1930) has made cross breeding experiments starting with two dogs of different races (Ceylonese poodle and dachs-hound). The differences between these dogs were 6 mm. in the width and 1 mm. in the length of the palatal vault. In the first filial generation (F_1) 3 dogs were examined, in the second (F_2) 9, and in the third (F_3) 5 dogs. In F_1, F_2 as well as F_3 the average width and length were less than those of the dogs belonging to the paternal generation. Gaspar emphasizes that because of the small number of cases it is impossible to determine the import of these differences, especially as the dispersion was relatively extensive. Hence the examination gives no explanation of the mechanism of heredity as to the question of the proportions of the upper jaw.

Ritter (1937 a, b, 1943), and *Le Roy Johnson* (1940) have investigated the results of cross breeding especially between dog races with normal occlusion e. g. Alsatian, Basset-dog and dachs-hound, and races with protrusion of the lower

jaw e. g. boxer, English bulldog and Pekinese. That both these types of occlusions occur constantly in the different races is naturally a proof of their genetic origin, and the aim of these experiments is therefore to try to determine the mechanism of heredity by transferring the existing predisposition to the next generations.

The type of occlusion, and the type of cranium on the whole, was in the first filial generation for the majority of dogs almost normal, while in the second generation a larger distribution appeared which has been accounted for by photographs and measurements. These facts should indicate that predisposition to the normal type of occlusion dominates over the predisposition to protrusion of the lower jaw. The number of dogs accounted for was, however, relatively small, and because no statistical calculations were made it is impossible to decide whether the differences found were significant. One is therefore scarcely entitled to draw any other conclusions from these experiments, than that cross breeding experiments with dog races with essentially different types of occlusion produce an offspring with a considerably greater variety in this respect than in the original races, and that these results indicate a complicated mechanism of heredity as to the characters in question which are thus likely to depend upon several more or less independent pairs of genes.

Ritter (1943) has also made a report on cross breeding between a large and a small rabbit with a tangible difference as regards the size of the cranium. The large female rabbit had a receding lower jaw producing a large overbite, while the small male rabbit was normal. From 4 rabbits of the first generation 3 showed too large an over-bite, and for two of them the disproportion was still larger than that of the mother, having a lower jaw too short as well as too narrow in relation to the upper jaw. In the second generation two normal rabbits were crossed with two of those which had malocclusions; from 12 rabbits 3 showed similar malocclusion though less marked. The number of animals

is of course too small to allow any conclusions to be drawn as to the mechanism of heredity. The investigation is, however, principally interesting because it treats the question to which extent malocclusions might occur as a consequence of a combination of genes resulting in large and small jaws and teeth.

If the aim is to analyse the significance of heredity of man as compared to that of environment, one utilises *twin-investigations*. It is presupposed that identical twins have the same genes, and therefore the difference between them is conditioned by environmental factors, while the difference between fraternal twins is conditioned by heredity as well as environmental factors. It has, however, been shown that the differences between identical twins too, might be conditioned by heredity where genotypical asymmetries are concerned (*Dahlberg* 1943). This question is of special interest in this connection, because it is conceivable that genotypical asymmetries of the teeth and the tooth position might appear in identical twins.

By means of special calculations one can obtain a measurement of the variability of heredity in relation to the variability according to non-hereditary factors. The correct method of calculation has been given by *Dahlberg* (1926 and 1942, see page 66). In those cases where an incorrect method of calculation has been used, a re-calculation giving the correct values has been made for the following.

Casuistic descriptions of the conditions of the occlusion in twins have been published by many writers. *Bergfors* (1923) can be given as an example. He accounted for 4 identical and 3 fraternal twin-pairs by means of photographs of the occlusal surfaces taken from models of their jaws. In the case of the 4 identical twin-pairs, only insignificant differences in the tooth position existed, and the shapes of the dental arches were practically identical. The fraternal twins showed considerably greater differences: two pairs had jaws essentially different in size, one of the twins having general bilateral crowding and the other an

even dental arch or unilateral crowding. In the case of the third pair, a difference, especially as regards the shape of the dental arch was found, being more tapering in one twin and broad and short in the other.

In some cases, identical twins with similar malocclusions have been described, e. g. by *Kelsey* 1923 (postnormal occlusion with protrusion of the front teeth of the upper jaw), *C. R. Baker* 1924 (prenormal occlusion), *Weitz* 1924 (symmetric crowdings in the upper jaw), *Steiner* 1927 (one pair of twins with postnormal occlusion and another pair with two teeth rotated precisely in the same way in the right side of the upper jaw), *Stanton* 1928 (postnormal occlusion and labial position of the lateral incisors of the upper jaw), *Burman* 1944 (impacted third molars in the lower jaw in mesioversion).

Packham (1931) has described a pair of identical twins both of them showing an edge-to-edge bite but only one had a positive tendency to crowding. The latter, considerably smaller than the twin-sister at birth, had been unhealthy, and also backward during childhood until 2 years of age. But after this period she developed so that at the examination (13 years) both twins were equally developed. *Axel F. Lundström* (1925) published a report concerning two pairs of identical twins, one pair having the same malocclusion (postnormal occlusion), and the other pair being similar as to the space of their teeth (both twins had crowding), while the occlusion was different one having a normal occlusion, and the other postnormal occlusion.

The condition of the occlusion in some cases of triplets, quadruplets etc. has also been described, and in these cases identical individuals were also characterized by a striking similarity and clearly distinguished from the other members of the triplets. *Schroeter* (1927) found that this was the case as regards over-bite in one case of triplets, and *Korkhaus* (1942) found the same in 5 cases of triplets and 2 cases of quadruplets as regards their over-bite, sagittal occlusion of the molars, the form of the dental arch

and palates and the relative space, respectively. *Ford* and *Mason* (1943) found that the Dionne quintuplets (all identical) had certain differences in the width of the dental arch (for instance at 7 years of age the difference at the second deciduous molar in the upper jaw was 1.8 mm. and 3.6 mm. for the same tooth in the lower jaw between the broadest and the narrowest). All of them showed an unusually narrow lower jaw in relation to the upper jaw.

The descriptions of the occlusions in a few cases of twins, triplets, etc. seem to speak for the significance of heredity as the origin of many malocclusions. However, it is conceivable that some of the cases were published because they have been especially interesting in this connection, with similarities for identical and dissimilarities for fraternal twins.

More systematic examinations of twins based on greater material have also been carried out, and the majority of the Germans work on this field has, on the whole, been carried out using the same methods. Variation of the occlusion has mainly been determined by means of estimations by eye, either by direct inspection of the mouth, or by the examination of plastermodels taken from the jaws. Any graduation of anomalies has not been made, but only the occurrence or non-occurrence of different anomalies has been registered. Guided by these notes the numbers of concordant and disconcordant twinpairs among the identical and fraternal twins, respectively, have been determined. Table 3 a and b show the results, in a concentrated form, obtained by the different writers.

The percentage of concordant twinpairs are for all the examined characters, higher for the identical than for the fraternal twins and for many of the characters these differences are significant. It must, however, be emphasized that clear definitions have not been given for the limit between normal cases and anomalies, which contributes an uncertainty of the results.

Different authors do not give the same definition for

medial diastema. *Siemens* and *Hunold* utilised this diagnosis for each space between the medial incisors, while others have limited the definition in as much as they have made an exception for such spaces between the medial incisors as could be considered as being more accidental in connection with the changing of teeth, or as being secondary spaces after extraction, or the migration of the teeth during paradental disease. *Korkhaus* also excluded spaces which he considered as being the result of thumb-sucking. But it must be considered impossible to decide in this way the cause of occurring diastemata. This must naturally make the given frequency figures uncertain, as in this way a certain margin is left for subjective judgement. That is also the case about diagnosis of the sagittal occlusion of the jaws, which according to *Angle* has been determined at the molars. None of the writers has given any indications as to how those cases were judged where migration of the molars might have taken place in connection with the extraction of teeth in the deciduous or permanent dentition. A report of the methods used would have been of benefit considering the difficulties associated with such endeavours at reconstruction.

In the Anglo-Saxon literature determinations of the occlusion in twins was made by *Bachrach* and *Young* (1927), who examined 301 pairs of twins out of which 130 were diagnosed as being identical, and 171 as being fraternal twins. Occlusions were accounted for in 107 identical and 132 fraternal pairs of twins (70 of the same sex and 62 of different sex). The distribution of different symmetrical types of occlusion is shown in table 4.

The frequency of discordant pairs of twins was calculated as being 26.2±2.9 % for the identical twins, while corresponding percentage for the fraternal twins was 51.5±3.0 %. The difference is 25.3±4.2 % and hence significant. This method of comparison is justified by the fact that the frequencies of the different types of malocclusions are approximately equal for both types of twins (normal

Table 3 a. **Concordance (++) and discordance (+−) of identical and fraternal pairs of twins as regards anomalies within the individual jaws according to different authors.**

Author	Type of twins	No. of pairs	Symmetrical rotations		Asymmetrical rotations		Symmetrical eruption outside the dental arch		Asymmetrical eruption outside the dental arch		Med. diast. Upper jaw		Med. diast. Lower jaw		Other diast.		Crowding of the teeth		Abnormally inclined teeth	
			++	+−	++	+−	++	+−	++	+−	++	+−	++	+−	++	+−	++	+−	++	+−
Siemens-Hunold (Munich) 1924	Ident.	56	27	11	9	19	3	2	5	8	13	13	4	2						
	Frat.	35	4	18	6	16	1	3	1	8	8	12	3	5						
Praeger (Tübingen) 1924	Ident.	26									2	1							1	2
Riepenhausen (Munich) 1925	Ident.	36	18	8	27	24	6	3	9	16	2	2	—	1						
	Frat.	52	5	34	15	27	—	8	2	25	1	4	—	2						
Lewin (Breslau) 1928	Ident	20							1	1	6	—								
	Frat.	12								1	—	2								

Köster (Munich) 1929	Ident.	33	9	10	4	34	1	4	1	17	9	1	3		8	2						1
	Frat.	73	14	22	7	92	2	7	1	44	12	13	2	3	1	10			1	9		
Korkhaus (Bonn) 1928, 1930, b 1939	Ident.	c:a 60	90	64	91	126					4	—					1	1				
	Frat.	c:a 40	40	47	55	105					2	5					—	2				
Brauns (Berlin) 1934	Ident.	31									1	1										
	Frat.	55									—	—										
Ritter (Breslau) 1937 b	Ident.	96	15	5	10	15	3	3	4	5	2	1					20	2				
	Frat.	126	6	35	1	31	—	6	—	3	1	2					4	36				
Frölich (Leipzig) 1938	Ident.	30	56	14			12	4			9	2							40	—		
	Frat.	59	16	24			—	10			9	12							24	24		
Total number[1]	Ident.	296	170	93	105	175	16	11	9	23	33	6	3		8	2	21	3	41	6		
	Frat.	365	76	128	63	228	2	23	1	48	24	34	2	3	1	10	4	38	25	33		
Total per cent with concordance	Ident.		64.6		37.5		59.3		28.1		84.6		100		80.0		87.5		87.2			
	Frat.		37.3		21.6		8.0		2.0		41.4		66.7		9.1		9.5		43.1			

[1] When adding up the examinations from Munich only the largest material is used as they partly seem to be based on the same pairs of twins.

Table 3 b. **Concordance (++) and discordance (+ −) of identical and fraternal pairs o twins as regards characters in the occlusion according to different authors.**

Author	Type of twins	No. of pairs	Normal sagittal occlusion (Angles class I)		Post-normal occlusion (Angles class II)		Pre-normal occlusion (Angles class III)		Linguo-version of upper premolars or molars		Open bite		Closed bite		Edge-to-edge bite	
			++	+−	++	+−	++	+−	++	+−	++	+−	++	+−	++	+
Siemens-Hunold (Munich) 1924	Ident.	56	36	7	2	2	—	1	—	—						
	Frat.	35	22	4	1	3	1	2	—	1						
Praeger (Tübingen) 1924	Ident.	26	12	0	1	1	2	—								
Riepenhausen (Munich) 1925	Ident.	36	27	3	3	—	—	1	1	1	—	—				
	Frat.	52	42	5	—	3	—	1	—	—	1	—				
Lewin (Breslau) 1928	Ident.	20			1	—			2	—	2	—	—	—		
	Frat.	12			—	—			—	—	—	1	1	—		
Köster (Munich) 1929	Ident.	33			5	3	—	—	5	—	3	—	4	—	—	1
	Frat.	73			2	7	—	3	1	9	—	1	2	1	—	3
Korkhaus (Bonn) 1928 etc.	Ident.	c:a 60			8	4	1	1			1	—	1	—		
	Frat.	c:a 40			5	6	1	—			—	—	—	—		
Ritter (Breslau) 1937 b	Ident.	96			6	2	2	—			1	—				
	Frat.	126			1	12	—	4			—	6				
Frölich (Leipzig 1938)	Ident.	30			—	—	—	—	—	1	1	—	4	3	—	—
	Frat.	59			2	7	—	2	1	5	1	3	10	12	—	3
Total number[1]	Ident.	265	48	7	21	10	5	1	7	1	8	—	9	3	—	1
	Frat.	310	22	4	10	32	1	9	2	14	1	11	13	13	—	6
Tot. per cent with concordance	Ident.		87.3		67.7		83.3		87.5		100		75			
	Frat.		84.6		23.8		10		12.5		8.3		50			

[1] When adding up the examinations from Munich only the largest material is used a they partly seem to be based on the same pairs of twins.

= 54.3 and 50.7 %, respectively; postnormal occlusion = 33.1 and 38.7 %, respectively; prenormal occlusion = 12.6 and 10.6 %, respectively). Similarly the coefficients of the mean square contingency show that identical twins

Table 4. **Percentage incidence of different combinations of normal occlusion and malocclusion of identical and fraternal pairs of twins and the coefficient of contingency for the different groups (according to Bachrach and Young, 1927).**

Type of occlusion	Identical twin pairs	Fraternal twin pairs		
		Same and different sex	Same sex	Different sex
Both the twins normal occlusion ...	43.0 ± 3.2 %	29.6 ± 2.7 %	27.1 ± 3.6 %	32.3 ± 4.0 %
One twin normal occlusion, the other postnormal occlusion	12.2 %	33.3 %	34.3 %	32.3 %
One twin normal occlusion, the other prenormal occlusion	10.3 %	9.1 %	10.0 %	8.1 %
Both the twins postnormal occlusion	25.2 %	17.4 %	17.1 %	17.7 %
One twin postnormal occlusion, the other prenormal occlusion	3.7 %	9.1 %	11.4 %	6.5 %
Both the twins prenormal occlusion	5.6 %	1.5 %	0	3.2 %
Number of pairs	107	132	70	62
Coefficient of mean square contingency	0.59 ± 0.06	0.15 ± 0.08	0.18 ± 0.10	0.27 ± 0.11

are more similar with regard to their occlusion than the different fraternal groups. But even this examination can be criticised as to the method used, because no specifications have been given as to how cases with suspected migration of the molars were judged. A report of the cases showing asymmetrical malocclusions would also have been of interest.

Practically in all identical twinpairs where one twin showed irregularities of the tooth position, the other showed the same anomaly either on the same side or on the opposite side.

Measurements to determine the variation of the occlusion naturally give a much greater objectivity. Several writers have also during their examinations of twins used measurements for the size of the teeth as well as the tooth position.

Reif (1928) examined on twins the significance of heredity as to the size of the teeth (employing material collected by Korkhaus). In all, 27 identical twinpairs were examined, 18 fraternal twinpairs of the same sex and 4 fraternal twinpairs of different sex. The mesio-distal size of the medial and lateral incisors of the upper jaw, and the first molars of the upper and lower jaws were measured with an accuracy of 1/10 mm. The differences in the pairs of twins were determined in this examination as in the majority of the following examinations, according to *v. Verschuer* (1925) i. e. half of the difference was expressed in percent of the mean value between the twins. A more simple way, and therefore a better measurement of the distribution in twinpairs is obtained if the whole differences are used. With due consideration to this, and in order to facilitate the comparisons with the values calculated in this work, there will in the following be made a doubling of those values calculated according to v. Verschuer.

Table 5. **Mean and standard error of the mean, $u \pm \varepsilon(u)$, of the intrageminal differences in tooth-size (mesio-distal width in mm), expressed in per cent of the mean value of corresponding tooth (according to Reif, 1928).**

Tooth	Identical twin pairs		Fraternal twin pairs	
	No.	$u \pm \varepsilon(u)$	No.	$u \pm \varepsilon(u)$
I_1 (upper jaw)	11	0.62 ± 0.14	10	2.50 ± 0.56
M_1 (» »)	11	0.0 ± 0.0	10	2.34 ± 0.52
M_1 (lower jaw)	10	0.0 ± 0.0	10	4.2 ± 0.94
I_2 right (upper jaw)	10	0.92 ± 0.20	10	10.78 ± 2.42
I_2 left (upper jaw)	10	1.94 ± 0.44	9	10.88 ± 2.56

In table 5 the deviations, re-calculated to whole differences as to the breadth of the teeth are given in percent of the corresponding mean values.

For the medial incisor of the upper jaw, and for the first molars of the upper and lower jaws Reif found complete symmetric similarities, which is the reason why no distinc-

tion was made for these teeth between the left and the right sides. The lateral incisors of the upper jaw on the other hand, showed larger variation as to the mesio-distal width of the left and right sides which fact necessitated that an individual determination for both sides had to be made.

Korkhous (1930 a) has extended on Reif's examinations by making similar measurements on a somewhat larger twin-material. Korkhaus' values as to the mean difference of the width of the teeth expressed in per cent are as given in table 6.

Table 6. **Mean and standard error of the mean, $u \pm \varepsilon(u)$ of the intrageminal differences in tooth-size (mesio-distal width in mm), expressed in per cent of the mean value of corresponding tooth (according to Korkhaus, 1930 a).**

Tooth	Identical twin pairs		Fraternal twin pairs	
	No.	$u \pm \varepsilon(u)$	No.	$u \pm \varepsilon(u)$
I_1 (upper jaw)	22	0.32 ± 0.04	19	4.26 ± 0.70
M_1 (lower jaw)	21	0.0 ± 0.0	16	5.98 ± 1.06
I_2 right (upper jaw)	22	0.60 ± 0.10	18	9.98 ± 1.66
I_2 left (upper jaw)	21	1.04 ± 0.16	16	11.84 ± 2.10

Korkhaus has also calculated the difference between left and right sides in the individual twin as to the breadth and thickness of the lateral incisors of the upper jaw within both groups of twins (42 identical and 33 fraternal twins). The following mean differences in per cent were found

Width of the lateral incisor of the upper jaw:
Identical twins 0.64 ± 0.06
Fraternal twins 2.46 ± 0.30

Thickness of the lateral incisor of the upper jaw:
Identical twins 0.34 ± 0.04
Fraternal twins 1.58 ± 0.20

The measured dimensions showed that, for the identical twins there was a greater similarity between the left and right sides than for the fraternal twins, a result which is dubious (cf. p. 96).

As Korkhaus', and especially Reifs' cases are few their results are of limited value. They only give an impression that genetical factors are of great importance. It is, however, difficult to understand that no differences were found between identical twins for M_1 as, at least, errors of measuring ought to be found (cf. p. 60).

Bratengeier (1934) has made similar measurements on 38 pairs of twins (20 identical and 18 fraternal pairs) for the mesio-distal width of the front teeth as well as the thickness and the height of the crowns of the same teeth. Out of these, the main interest refers to the mesio-distal width of the teeth from the point of view of the tooth-position (table 7).

Table 7. **Mean and standard error of the mean, $u \pm \varepsilon(u)$, of the intrageminal differences in tooth-size (mesio-distal width in mm), expressed in per cent of the mean value of corresponding tooth (according to BRATENGEIER, 1934).**

Type of twins	Side of jaw	I_1		I_2		C	
		No.	$u \pm \varepsilon(u)$	No.	$u \pm \varepsilon(u)$	No.	$u \pm \varepsilon(u)$
				Upper jaw			
Identical	left	20	1.88 ± 0.30	19	4.24 ± 0.68	8	3.16 ± 0.80
	right	20	2.04 ± 0.32	20	4.54 ± 0.72	8	0.82 ± 0.20
Fraternal	left	18	6.32 ± 1.06	18	8.22 ± 1.38	7	7.82 ± 2.10
	right	18	5.34 ± 0.90	18	6.16 ± 1.02	8	5.08 ± 1.28
				Lower jaw			
Identical	left	20	2.14 ± 0.34	20	1.02 ± 0.16	11	5.92 ± 1.26
	right	20	2.54 ± 0.40	20	1.06 ± 0.16	11	3.72 ± 0.80
Fraternal	left	17	6.46 ± 1.10	18	6.30 ± 1.06	12	6.92 ± 1.42
	right	18	5.32 ± 0.88	18	5.52 ± 0.92	12	4.38 ± 0.90

Bratengeier's results show on the whole a higher variability for the fraternal twins with significant differences

between them and the identical twins in the mean percental difference for several teeth.

Goldberg (1929 and 1930) has examined 15 pairs of identical twins from the age of 3½ to 24 years as regards the shape of their dental arches by means of a number of measurements in the transversal and sagittal planes, made on plaster casts of the jaws.

For each twin the difference was determined between left and right side (bilateral differences) and for each pair, the difference between left and right values (unilateral differences). Goldberg found somewhat greater differences in the former case than in the latter, but since no statistical treatment of the material has been made, it is impossible to determine whether the difference was significant or not. Goldberg states, that the relation between unilateral and bilateral differences constitutes a measurement of the effect of heredity in relation to that of environment; the less the quotient, the greater the significance of heredity. Against this statement it must be emphasized, that it is impossible to determine the influence of heredity by means of examination on identical twins only. In order to do this, determinations on fraternal twins are also necessary.

Goldberg has also observed the occurrence of mirror-images in the dentition by using 50 pairs of twins. Two pairs of twins had congenitally missing maxillary lateral incisors, on the left side for one twin, and on the right side for the other. One pair had one of their medial incisors rotated in a mirror-like way. In another pair the one twin had 2 roots in the first premolar on the left side, and the other on the right side. Other observations with converted symmetry were a rotation of the premolars, one-sided open bite, and one-sided cross-bite. Mirror-images in the occlusion were compared with the occurrence of mirror-images as regards left- and right-handedness, but no parallelism was found. On the other hand, a connection between left- and right-handedness and preference of chewing on the same side was found in 6 pairs of twins.

Less (1934) has by means of measurements examined the shape of the dental arch of the upper jaw, and the shape of the palate in 82 pairs of twins of the same sex: 44 identical and 38 fraternal twins (these examinations have also been accounted for by *Zeiger*, 1934). The age varied between 5—6 and 21—22 years, the majority being between 7 and 12 years. In order to compare the degree of similarity for the two types of twins, the mean difference in per cent (u) was calculated according to *v. Verschuer*'s method. To which extent the environment contributes to the variability of fraternal twins, das determined according to *Lenz-Verschuer* (1928) as being $100 \times \frac{u\,(\text{identical twins})}{u\,(\text{fraternal twins})}$. This formula is incorrect. If the calculations are made according to *Dahlberg*'s (1926) formula (see page 67) the following result is obtained (table 8).

Table 8. **Variation in length and width of the dental arch and height of the palatal vault determined by calculating the mean of the intrageminal differences in per cent of the mean value of the corresponding measurement, $u \pm \varepsilon(u)$, for identical and fraternal twins (according to Less, 1934). The ratio between heredity and non-heredity according to the formula by Dahlberg is also given.**

Measurement	Identical twin pairs		Fraternal twin pairs		Heredity / Non-heredity
	No.	$u \pm \varepsilon(u)$	No.	$u \pm \varepsilon(u)$	
Width of the dental arch at M_1	43	2.20 ± 0.24	38	4.36 ± 0.50	1.7
» » » » » » P_1	38	3.56 ± 0.40	35	5.52 ± 0.94	1.2
Length » » » » from M_1—I_1	44	2.88 ± 0.30	38	4.22 ± 0.48	1.1
Greatest height of palatal vault	44	9.64 ± 1.02	38	16.10 ± 1.84	1.3
Height of palatal vault between incisive papilla and M_1 distally	44	11.14 ± 1.18	38	17.48 ± 2.00	1.1
Height of palatal vault at M_1 distally	44	12.02 ± 1.28	38	17.78 ± 2.04	1.1

Less' material shows a significant, or almost significant difference in the variability of the twins, which is higher for fraternal twins than for identical twins as regards

several characters, showing thus the significance of heredity.

Concerning the height of the palatal vault, Less obtained essentially higher values for the mean difference, in identical pairs of twins than for other caracters, and she explains this as a proof that the effect of environmental factors is particularly great as regards the palatal height. This conclusion is, however, not justified as the difference may also depend on a greater error of measurement during the registration of this character. Whether this explanation is correct cannot be determined as the error of measurement was not calculated, but is probable because the quotient between heredity and environment does not to any certain degree differ from those of the other characters. The relationship between heredity and environment varies between 1.7 and 1.1 with the strongest hereditary influence for the width of the dental arch at M_1, and the weakest for the length of the dental arch. To which extent the existing differences are due to random variation or caused by errors of measurement is impossible to determine.

In order to determine the profile of the gums, and the shape of the dental arch, the general similarity was also estimated by means of estimations by eye as to whether concordance or discordance existed. The following frequency of discordant twinpairs was obtained for the two types of twins.

	Ident. twins	Fratern. twins
The profiles of the palate	33 %	79 %
The shape of the dental arch	26 %	83 %

The differences in frequency are so great that in spite of the subjective method applied, they have much in their favour for the theory that heredity is of significance to the characters in question.

Korkhaus (1939) has also examined the size and shape of the dental arch by measuring the anterior and posterior width of the dental arch (at P_1 and M_1), and the length of

the dental arch (from the line connecting P_1 to the medial incisors). Identical twins were on the whole more concordant than fraternal twins (see table 9). Corrected values as to the quotient between heredity and environment are also included in this table.

Table 9. **Variation in length and width of the dental arch and height of the palatal vault determined by calculating the mean of the intrageminal differences in per cent of the mean value of the corresponding measurement, $u \pm \varepsilon(u)$, for identical and fraternal twins (according to KORKHAUS, 1939). The ratio between heredity and non-heredity according to the formula by DAHLBERG is also given.**

Measurement	Identical twin pairs		Fraternal twin pairs		Heredity / Non-heredity
	No.	$u \pm \varepsilon(u)$	No.	$u \pm \varepsilon(u)$	
Upper jaw					
Width of the dental arch at M_1	52	1.28 ± 0.12	39	4.20 ± 0.48	3.1
» » » » » » P_1	40	2.88 ± 0.32	32	5.16 ± 0.64	1.5
Length » » » » from P_1–I_1	52	1.72 ± 0.18	39	5.22 ± 0.58	2.2
Height of palatal vault	52	5.04 ± 0.50	39	8.70 ± 0.98	1.4
Lower jaw					
Width of the dental arch at M_1	47	1.66 ± 0.18	33	4.82 ± 0.60	2.7
» » » » » » P_1	40	2.88 ± 0.32	30	4.26 ± 0.54	1.1
Length » » » » from P_1–I_1	47	1.70 ± 0.18	33	6.30 ± 0.78	3.6

Korkhaus found higher values than Less for the significance of heredity in relation to that of environment, which is explained by the fact that Korkhaus found less variation in the identical twins than Less. As regards the width of the dental arch at M_1 the difference is significant. The explanation of this might be differences in the age of the pairs of twins. This is, however, impossible to control as Korkhaus has not reported the age of the twins he examined. Another possibility is that the method of measuring employed by Korkhaus was unsuitable giving possibilities for memory influences, while measuring the identical twins.

Noack (1941) has examined the conditions of the occlusion in 3 identical and 7 fraternal pairs of twins. A large

number of determinations were made of the shape of the palatal vault, the size of the dental arch, their relation to each other and to Simon's cephalometric planes. Noack emphasizes that his material is far too limited to allow any general conclusions to be drawn, hence his work is mainly of methodological interest.

Investigations of families to determine the significance of heredity on the size of the permanent teeth (width, thickness and height) has been made by *Hohl* (1934) for the canines, and by *Martin* (1934) for the incisors. Both writers determined the correlation between the mean value of the parents' measurements and those of the individual children. Hohl made, in this connection, a correction of the values found for the females so that these were increased with the mean difference between the sexes. Hohl examined 100 families with altogether 76 sons and 66 daughters, and Martin examined 50 families having 33 sons and 50 daughters. The obtained correlation coefficients between the mean value of the parents, and that of the children as to the mesio-distal width of the teeth appear in table 10.

Table 10. **Correlation coefficient, r, showing the connection between the mesio-distal width of different teeth of the parents and the corresponding width of the teeth for their children (according to** Hohl, **1934 and** Martin, **1934).**

Author	Tooth	$r \pm \varepsilon(r)$	Tooth	$r \pm \varepsilon(r)$
Martin	I_1 upper jaw	0.46 ± 0.09	I_1 lower jaw	0.31 ± 0.05
»	I_2 » »	0.38 ± 0.09	I_2 » »	0.51 ± 0.08
Hohl	C » »	0.42 ± 0.08	C » »	0.40 ± 0.07

For all teeth, significant, positive correlation coefficients were obtained, which shows the significance of genetical factors for the size of the teeth.

Descriptions of similarities in the toothposition within individual families have been given by many writers. So far as the descriptions concern fairly usual malocclusions they have no appreciable value, as it is impossible to deter-

mine whether the coincidence in two or more members of the family are either due to accident, and conditioned by environment, or dependent on hereditary factors. On the other hand, in the case of more seldom found characters, the probability that the hereditary factors are the cause of similarities becomes greater. From this point of view, the following descriptions of families can especially be mentioned.

Levy (1907) has accounted for one family with 9 children out of which, 7 showed disturbances in the eruption of the canines in the upper jaw with impactions, or other deviations in the position.

Zentler (1916) has described 3 families with lingual occlusion of the front teeth in the upper jaw, and in one of these families the father and 3 children out of 6 had this malformation. *Knoche* (1916, 1921), *Weil* (1922), *Kyoto* (according to *Keeler,* 1935), *Hotz* (1938), *Sawin* (1939) and *B. A. Anderson* (1943) have also described families in which several members had prenormal occlusion of the lower jaw.

Crosman (1927) has described how 3 cousins, and the father of one of them showed a malformation of the canine and the first premolar, these teeth having changed places.

More systematic examinations of families have also been made regarding the size and shape of the jaws, and the toothposition. The heredity of the so-called Habsburgian lower jaw has attracted special interest, and works explaining this question have been published by *Galippe* (1905), *Rubbrecht* (1929, 1930, 1939), *Hæcker* (1911—12), *Strohmeyer* (1911, 1912), *Kantorowicz* (1915), *Mayoral* (1931) and *Aguilar* (1933). According to a genealogical tree published by Rubbrecht, extending from Ernest de Fer (1377—1424) to the end of the 16th century, the Habsburgian lower jaw can be traced in an unbroken line through 9 generations. In this connection, however, it ought to be stressed that mandibular prognathism registered in this way does not necessarily include malocclusion of the

teeth. At least in some of the cases, it may also be a question of protruding chins with normal occlusion.

Rubbrecht (1939) also published other genealogical trees with an occurrence in families, of what he refers to as mandibular prognathy or maxillary retrognathy. In this connection, he accounted for 14 families within 5 genealogical trees in which this diagnosis was made for at least one member of each family. The type of occlusion was determined by means of photographs, or through direct examinations of each patient. In one of the pedigrees, the occlusal condition was studied cephalometrically. The different methods of diagnosis make it, however, difficult to obtain a survey of the results achieved. The same verdict may be given about the two genealogical trees published by Rubbrecht with mandibular retrognathy or maxillary prognathy, and one genealogical tree with anterosuperior hypergnathy.

Iwagaki (1938) collected, by interrogating 2461 japanese students, information as to the occurrence of mandibular prognathism amongst their parents, brothers and sisters. Since no clear definition, however, has been given as to the meaning of the diagnosis, and since the information has not been checked, the examination is not likely to be of any value even though Iwagaki tried to treat his material mathemathically. Apart from this, the agreement he obtained between the theoretical and empirical values was poor. According to these circumstances, no conclusion can be drawn from the investigation as to the hereditary mechanism in mandibular prognathism.

As regards closebite, *Meier* (1930), and *Korkhaus* (1939) have given casuistic descriptions of genealogical trees showing the occurrence of malocclusion within families.

Medial diastema in the upper jaw has been examined by *Terwee* (1922) (7 families with anomalies in two or more members of each family), and by *Weninger* (1933). The latter examined 26 families, and found that 58.2 % of the children in discordant marriages (24 marriages with a total

of 91 children) showed trema. The writer interprets this fact as an indication of this character being due to dominant genetical factors. As a further support of this conception, she states that in all the families, with the exception of two, having one child or more suffering from trema, at least one of the parents also had this character.

Kadner (1929) has examined parents and children of 37 families by means of measuring the width of the dental arch at different teeth, and making estimations as to the shape of the different regions of the jaw, and the occurrence of malocclusion respectively. No comparisons of the measurements were made, and Kadner's conclusion that the different parts of the occlusion (the middle part of the upper jaw, the sides of the upper jaw, the lower jaw, the teeth and the palatal bone) are inherited independently, can hardly be considered proved by the given descriptions. The work is richly illustrated, and the extensive occurrence of a strong overbite in several families has much in its favour as to the significance of heredity in this respect.

Bergfors (1936) examined the correlation between parents and children as to the transversal measurements of the dental arch, and the height of the palate in 67 families. The correlation coefficients *(r)* found, show a positive correlation between parents and children ($r = +0.36 \pm 0.14$), and between brothers and sisters ($r = +0.40 \pm 0.13$) thus showing the significance of genetical factors.

Bauwens (1932) accounted for 6 genealogical trees in which occurred serious so-called rickets-like changes of the jaws. The writer found in the different families, an accumulation of the symptoms generally supposed to characterise rickets in the jaws, such as hypoplasia of the enamel, narrow upper jaw, open bite, and his interpretation is that a disposition to rickets should be hereditary, while, on the other hand, the existing anomalies of the jaws should not directly be dependent on the effect of the hereditary factors.

Moore and *Hughes* (1942) have examined the occurrence

in families of, among other things, different characters of the jaws. The material consisted of 78 families consisting of 135 parents, and 130 children. The registration of the different characters was made by subjective grading into a small number of classes. The significance of heredity was determined by making so-called genetical triangles consisting of father, mother, and one child. For each character, a table was given over the different occurring types of triangles as regards to the concordance, or discordance between the persons involved. As a statistical treatment of the material has not been made, it is impossible to determine whether the results obtained are due to random variation or not. The heterogenity as to the age of the children (between one year and upwards) constitutes another source of error.

Observations of the result of crossings between different races, in regard to occlusion, is very rarely met with in literature. *Abel* (1932) has examined the cross between Bushmen, Hottentots and Negroes. The size of the jaws were determined by means of measuring the length of the dental arch in the upper and lower jaw. In this respect great differences were found (approx. 10 mm.) between the Bushmen and the Hottentots on one side (18 skulls) and Negroes (7 skulls) on the other side. The mean value of the skulls of the mixed races (38) lay between that of the original races. As to the toothposition, Abel states that the skulls belonging to the mixed races showed, to a remarkably high degree, malocclusion of the teeth, and especially crowding of teeth was found. The writer interprets this fact as a proof that the size of the teeth and of the jaws are inherited independently from each other, so that in bastards, the combination of teeth of the taller races and jaws of the smaller races, or vice versa, might occur. This conclusion, however, does not seem sufficiently supported considering the small number of cases examined, and that there is no information as to the occurrence of crowding in the pure races.

To which extent environmental factors *in utero* might affect the occlusion has not been examined, and is of course, also very difficult to analyse. It is conceivable that, during delivery certain slight disturbances might occur, but it is probable that these disturbances are of a temporary nature. Any satisfactory systematic examinations of this problem have, however, not been carried out.

Actually, later environmental factors have been the main subject of discussion in literature. Among these factors, fingersucking has been the object of several examinations which indicate that this factor is mostly of a temporary nature, and of minor significance as far as malocclusions in adults is concerned.

Another factor, which has been very much discussed, is the extraction of teeth. The examinations mostly show that the extraction of deciduous teeth is of minor importance. This problem, however, cannot be considered as being fully solved. As far as the extraction of permanent teeth is concerned the effect may naturally be stronger, above all, in preventing the development of malocclusions, but on the other hand, the effect does not seem to be so great where the producing of malocclusions is concerned.

It has also been questioned whether malocclusions might be caused by the slighter functioning of the jaws characterizing the present time, in contrast to earlier periods of time. This factor can hardly be of noteworthy significance, because if that were the case, malocclusions would be an almost general phenomenon.

The significance of diseases caused by vitamin deficiency, especially rickets, has been the object of many examinations, and they indicate that the significance of this factor is not great, at least when it concerns the relatively slight attacks which are generally encountered nowadays.

Examinations of identical and fraternal twins show greater deviations for the latter when compared to the

former as to the size of the teeth, as well as the tooth position and occlusion, thus indicating the significance of heredity in this respect. The use of subjective limits between anomalies and normal cases in the majority of these examinations, however, makes the judging of the obtained results difficult.

Calculations of the significance of heredity as compared to that of environment in the width and length of the dental arch, and in the height of the palatal vault have given quotients between heredity and environment varying between 1.1 and 3.6.

Examinations of families have shown significant correlation between parents and children as regards the size of the teeth, and as to the width of the dental arch, and height of the palatal vault also between brothers and sisters. Descriptions of families indicating the significance of genetic factors have been given for several malocclusions. As to the mechanism of heredity, it has been discussed whether dominant hereditary factors contribute to the origin of prenormal occlusion, close-bite and medial diastema. However, regarding the two last mentioned types of anomalies, the material published is far too limited to be accepted as a proof. The material for cases of prenormal occlusion, it is true, is more comprehensive, but on the other hand the methods of diagnoses employed are so uncertain, that the results must be treated with greatest caution.

Cross-breeding between highly contrasted dog races having normal occlusion, and races having prenormal occlusion of the lower jaws, or short jaws, point to the fact that these characters should be governed by several more or less independent pairs of genes.

CHAPTER II.

METHODS OF INVESTIGATION

When examining the mesio-distal widths of the teeth, the easily reached I_1, I_2 and C were measured directly, while P_1, P_2 and M_1 were measured on models of the jaws made of hard model-plaster, reproduced from impressions made with so-called hydrocolloidal impression compounds (Dentocoll and S. S. W. Elastic Compound). As a measuring instrument a slide gauge was used, and the reading was made with an accuracy of 0.1 mm. The one pair of legs of the slide gauge had been ground to sharp points, and the other pair to edges with a length of 2.7 mm. (fig. 1 a). The latter were mostly applied to the front teeth, whose mesial points of measurement are often situated more incisally than the distal points. In such cases the slide gauge was placed perpendicularly to the facial surface, and parallel to the occlusal plane as shown in fig. 1 b. For M_1 in the upper jaw, the distal point of contact is

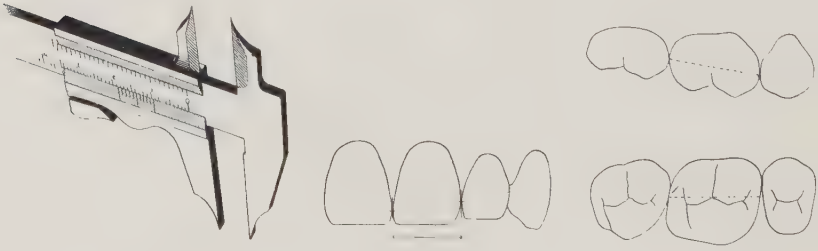

Fig. 1. Measuring of tooth-breadths. a. slideguage used. b. measuring of incisors with contact-points at different level has been made parallel to occlusion plane. c. measuring of 1st molars in the upper jaw has been made along dotted lines.

displaced both in an apical and lingual direction in relation to that of the mesial point. These teeth were measured with the pointed ends of the slide gauge as shown by the dotted lines in fig. 1 c.

The following characters have been measured as to the position of the teeth within the individual jaws, and to the occlusion of the jaws:

1. The space and the space-difference (= space minus the sum of the mesio-distal sizes of corresponding teeth) of the dental arches.
2. The width, length and length expressed in percent of width of the dental arches.
3. The inclination of the teeth.
4. The height of the palatal vault.
5. Occlusal deviations in the sagittal plane.
6. Occlusal deviations in the vertical plane.
7. Occlusal deviations in the transversal plane.

All these determinations were made on plaster-models. The occlusal position was determined by help of wax-indices, which as a rule reproduces the occlusion correctly. In some cases it appeared that the individual, when biting in the wax, had pushed the lower jaw slightly forward. But, in such cases it was not difficult to make a correction of the model so that the true occlusion was reproduced.

Because of practical difficulties, it was impossible to take X-rays except in some few cases.

The registration of the above mentioned characters of the jaws was carried out in the following manner:

1. *The space and the space-difference of the dental arch.* The space of the dental arch was measured in six sections in each jaw for each pair of teeth from M_1 to M_1. Section 1 in the upper jaw includes M_1 and P_2 on the left side, and as points of measurement, the distal point of contact at M_1 and P_1 respectively were used, section 2 includes the following pair of teeth, P_1 and C etc. (fig. 2). Medial diastema was measured separately, thus the total

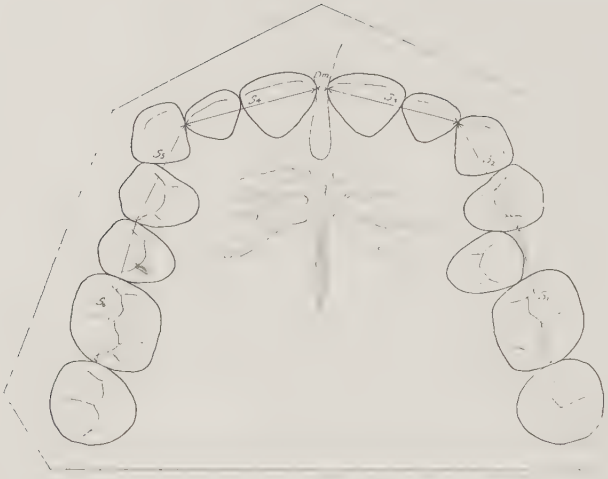

Fig. 2. Measuring of the space in the dental arch. The total space is given as the sum of six sections of the arch and, if such occurs, of the medial diastema (D. m.).

arch-space constitutes the sum of the six sections, and the width of possibly existing medial diastema.

The space-difference was obtained as the difference in mm. between the arch-space, and the sum of the tooth-bredths within the measured regions of the jaw. If a tooth was injured to a degree that made it impossible to measure the bredth, the value of the same tooth on the opposite side was used. If it was impossible to measure anyone of a corresponding pair of teeth on both sides of the jaw the probable breadth was determined from the adjoining teeth, namely, by the relation between the arithmetic means of the teeth according to previously made examinations (1944) carried out by the writer (table 11).

The spaces after extracted first molars, contract often more or less completely, mainly through the mesial migration of M_2, and, to some degree also, through distal migration of teeth in front of M_1 (or mesial displacement of these teeth failing to appear). Therefore, if one measures the space from the mesial surfaces of M_2 one will find that in

Table 11. **The ratio between arithmetic means of the tooth-breadth of different teeth expressed in per cent.**

+6+	in	per	cent	of	+4+	= 149.7 %	−6−	in	per	cent	of −4−	= 156.3 %
+5+	»	»	»	»	+4+	= 96.3 %	−5−	»	»	»	» −4−	= 101.9 %
+4+	»	»	»	»	+5+	= 104.2 %	−4−	»	»	»	» −5−	= 98.2 %
+3+	»	»	»	»	+4+	= 108.9 %	−3−	»	»	»	» −4−	= 94.2 %
+2+	»	»	»	»	+1+	= 76.6 %	−2−	»	»	»	» −1−	= 110.5 %
+1+	»	»	»	»	+3+	= 111.9 %	−1−	»	»	»	» −2−	= 90.4 %
+4+,							−4−,					
+5+	»	»	»	»	+6+	= 130.6 %	−5−	»	»	»	» −6−	= 129.2 %

these cases essentially smaller values for the space-difference are obtained, while a registration from the distal contact of P_2 gives too high values as compared with those of the primary space. Therefore in these cases, it seems better to start measuring from the first premolar. For jaws with loss of M_1, the space-difference has therefore been determined from the distal contact-point of P_1, thus, where there is a loss on one side, only five sections were used, and on both sides only four out of six sections were used.

As to extractions of teeth in front of M_1, one must consider that these, too, involve a decrease in the total space even though the effect may not be so great. If such extractions have taken place one must, however, take into consideration that in some cases the teeth have been extracted as a treatment for crowding, which to a much smaller degree is the case as regards M_1. If one, therefore, in these cases excludes sections with extraction, a more or less misleading result is obtained. For this reason I have in such cases calculated the space-difference for all sections.

Besides determining the total space, special calculations of the space for the sections 1+2, and 3+4 (including medial diastema) have been made (cf. fig. 2).

2. *The size of the dental arch* has also been determined by means of measurements. The width of the dental arch was measured at P_1 and M_1 in the upper and lower jaw. In the upper jaw the points of measurement assigned by *Pont* have been employed, while in the lower

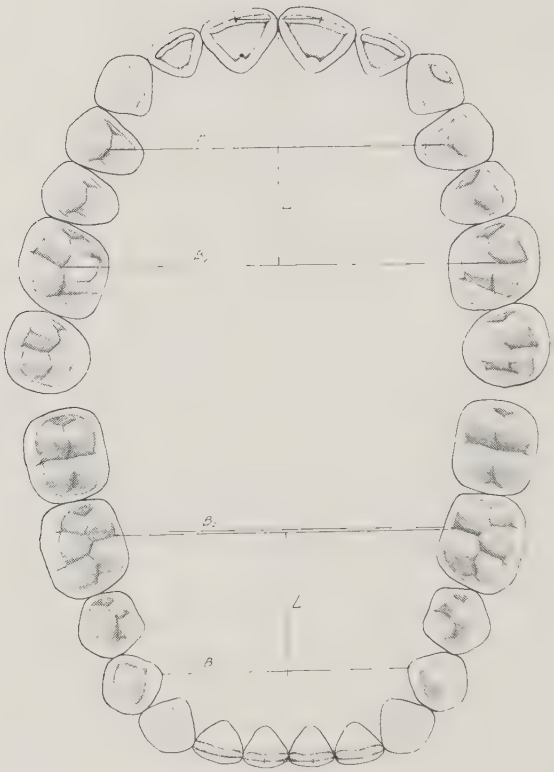

Fig. 3. Measuring points for width and length of dental arches.

jaw the measurement was made from the innermost point of the crown, perpendicular to the curve of the dental arch of the teeth in question (fig. 3).

In the upper jaw the slide gauge was used, and the legs with sharp points were applied to the teeth. In the lower jaw a special compass with points perpendicular to the legs was used. The width of the distance found in this manner was measured with the slide gauge.

The length of the dental arch was measured by means of a specially designed instrument (fig. 4), which is a modification of *Korkhaus'* three dimensional compass. The points of the compass are adjusted to the distance between

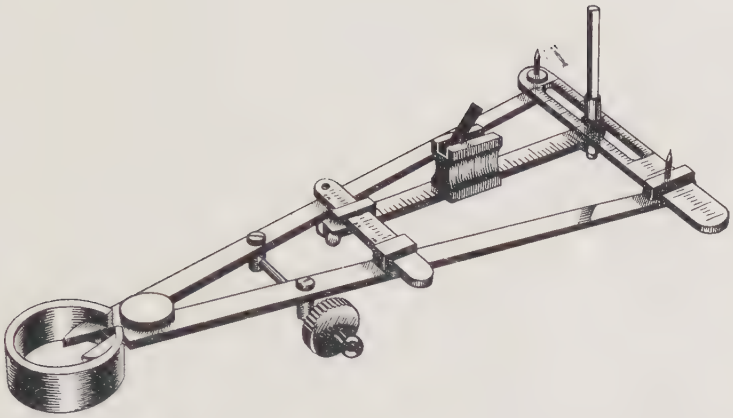

Fig. 4. Instrument used for measuring of the length of the dental arches, the inclination of the upper medial incisors and the height of the palatal vault.

the points of measurement of the first molar by the aid of a scale on a connection between the points, which is attached to one of the points of the compass while the other end runs in a slide. The reading is done at one edge of the slide. From the connection between the points of the compass there runs a metal-rod, which is adjustable laterally, so that the one end can always be placed in the middle of the points of the compass, which is done by a special scale on the connection. The other end is supported by a cross-bar on the compass and this, too, is adjustable laterally. Along the metal-rod there is a runner, which has the same height as the points of the compass. While measuring the length of the dental arch, the points are placed in the central fossæ of M_1 in the upper jaw, and in the fissure between the lingual cusps of M_1 in the lower jaw, while the runner is adjusted so that its posterior edge is on level with the centre of the medial incisor's edge. If these are at different levels, the length of the dental arch at each incisor is measured individually, and the mean value of the two measurements is given as the length of the arch. If the incisor's edge is worn down to a plane

surface the instrument is placed against the anterior edge of this surface. When registrating, the one point of the slide gauge is placed in a little depression in the middle of the points of the compass, and the other point of the gauge on the posterior edge of the runner, and in this way the length can be read with an accuracy of 0.1 mm.

3. As to the *inclination of teeth* only the medial incisors of the upper jaw have been measured, these teeth seeming to vary most in this respect. The same instrument as was used for measuring the length of the dental arch has been employed. The points of the compass were placed in the central fissures of M_1, and the compass was adjusted in the same way as when measuring the height of the dental arch. The inclination of the incisors is determined by means of a hinged rod 10 mm. long which is adjusted in such a way that it is resting against the facial surface of the tooth to be measured (fig. 5). The value of the in-

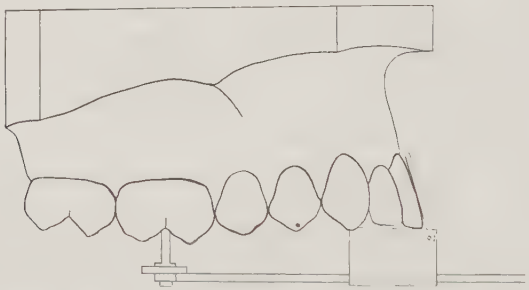

Fig. 5. Measuring of the inclination of upper medial incisors.

clination is obtained by measuring the distance between the end adjusted of the rod and the upper posterior edge of the runner. Left and right incisors have been registered individually, and in cases with different inclinations, the mean value constitutes a measurement of the inclination of the incisors.

4. The *height of the palatal vault* is measured perpendicularly to the occlusal plane at the first molars from the

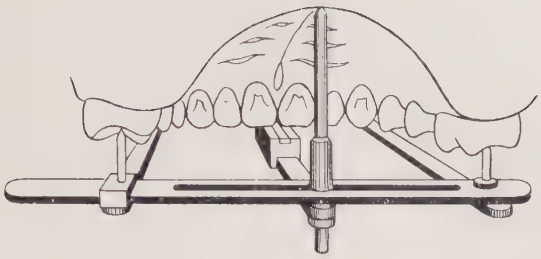

Fig. 6. Measuring of the height of the palatal vault.

level formed by the central fissures of M_1, and to the highest point of the palatal vault between these points of measurement (fig. 6). The measurement was made with the same compass as mentioned above. The points of the compass are adjusted to the distance obtained for the width of the dental arch at M_1, and the metal-rod is placed with the one end in the middle of the points of the compass. Through a hole in the metal-rod, and supported by a case at the same level as the points of the compass there runs a semicircular metal-rod with slightly rounded ends. The compass is placed against the upper jaw with the points in the fissures of M_1, and the runner for measuring the length of the dental arch is placed against the edge of the incisors. The height of the palate is measured by a slide gauge with an accuracy of 0.1 mm. One of the legs is placed against the case and the other against the outermost mark of the scale which is on the semicircular metal-rod.

5. The occlusion in *the sagittal plane* was registered at the molars and at the incisors. The sagittal occlusion of the molars was determined at M_1 by measuring the mesio-distal distance between the mesio-facial cusp points of M_1 in the upper jaw, and the fissure between the mesio- and disto-facial cusps of M_1 in the lower jaw (fig. 7). The distance was measured with the slide gauge with an accuracy of 0.1 mm. If the registration point in the lower jaw lies behind that of the upper jaw (postnormal oc-

Table 12. **The error of measurement in mm (the standard error of a single determination, σ_i) for tooth-breadth (mesio-distal width).**

σ_i is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{2n}}$, where d is the difference between two measurements of the same individual and n the number of double determinations. M = arithmetical mean of the measures in both determinations.

Tooth	Left side			Right side			Mean value of left and right side		
	No. (= n)	σ_i	σ_i in % of M	No. (= n)	σ_i	σ_i in % of M	No.[1] (= n)	σ_i	σ_i in % of M
Upper jaw									
I_1	40	0.06	0.69	40	0.05	0.57	38	0.05	0.52
I_2	39	0.08	1.21	39	0.07	1.05	40	0.07	0.98
C	38	0.05	0.72	36	0.04	0.56	39	0.04	0.51
P_1	37	0.09	1.33	36	0.09	1.24	38	0.09	1.22
P_2	37	0.08	1.16	37	0.08	1.15	37	0.09	1.25
M_1	37	0.16	1.54	37	0.13	1.25	37	0.12	1.18
Lower jaw									
I_1	40	0.03	0.61	40	0.04	0.79	40	0.04	0.77
I_2	40	0.08	1.34	40	0.08	1.41	40	0.06	1.03
C	39	0.05	0.67	40	0.07	1.09	40	0.05	0.79
P_1	38	0.11	1.48	37	0.10	1.36	39	0.10	1.39
P_2	33	0.15	2.11	34	0.11	1.48	35	0.10	1.39
M_1	36	0.16	1.46	37	0.14	1.24	37	0.15	1.37

[1] If only one side could be measured the figure of this side has been used.

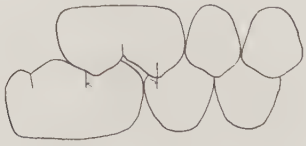

Fig. 7. Measuring of mesio-distal occlusion at the first molars.

Table 13. **The error of measurement (the standard error of a single determination, σ_i) in mm for arch-space and space-difference measurements.**

σ_i is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{2n}}$, where d is the difference between two measurements of the same individual. M = arithmetical mean of the measures in both determinations.

Measure	Space	Jaw	No. of double determinations	σ_i	σ_i in per cent of M
Whole dental arch...	abs.	upper	40	0.41	0.43
	diff.	»	40	0.31	—
Section 1 + 2.....	abs.	»	39	0.16	0.49
	diff.	»	38	0.24	—
Section 3 + 4.....	abs.	»	39	0.21	0.67
	diff.	»	39	0.30	—
Whole dental arch...	abs.	lower	39	0.42	0.49
	diff.	»	40	0.55	—
Section 1 + 2.....	abs.	»	40	0.14	0.44
	diff.	»	40	0.36	—
Section 3+4.....	abs.	»	40	0.19	0.86
	diff.	»	40	0.35	—

clusion at M_1), the distance has been indicated as negative, and in the opposite case as being positive (prenormal occlusion at M_1).

One disadvantage with this method is that M_1 in the lower jaw has a varying numbers of cusps, since there are types of teeth with 3 and 2 facial cusps. In the latter type, the fissure which is used as a starting point for measuring lies nearer the center of the tooth than in the former type. Cases where the same general position exists for the dental arches ought, therefore, as regards the former type to show rather more negative values of the occlusion for the molars than are found in the latter.

This difficulty is avoided by using *Seipel's* (1946) deter-

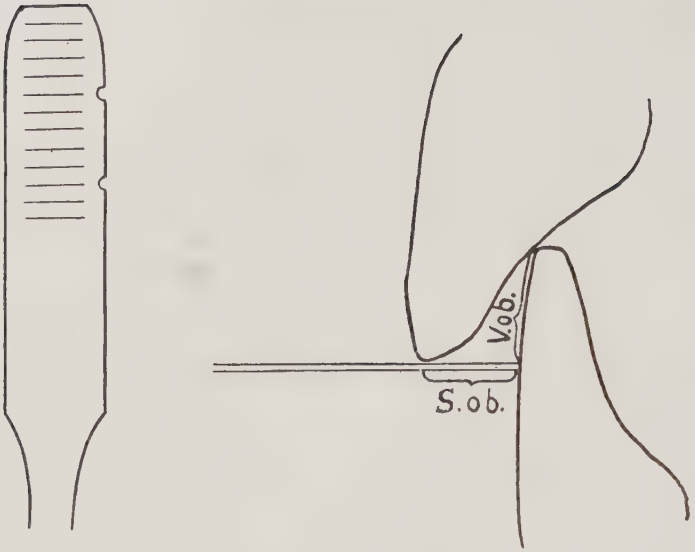

Fig. 8. Measuring of sagittal and vertical overbite.

mination, according to which the position of the molars is measured as being the difference in the mesio-distal plane between the mesial points of contact of M_1 in the upper and lower jaws. The reason why I, nevertheless, have used another method is that I consider this source of error to be of a relatively little importance as compared with the advantage of obtaining a value, which shows directly the deviation from the ideal occlusal relationship at M_1.

The frontal sagittal relationship between the jaws was determined as being the sagittal over-bite at the medial incisors in the upper jaw (fig. 8), and is defined as the mean value between the two distances from the facial surface of the lower incisors to the center of the facial edges of the medial incisors in the upper jaw. The distance is parallel with the occlusal plane and perpendicular to the dental arch at the points of measurement. The measurements were made with a metal-spatula, graduated in mm. The spatula was placed with its scale against the lower

Table 14. **The error of measurement (the standard error of a single determination, σ_i) in mm for width of dental arch at P_1 ($= B_1$) and at M_1 ($= B_2$) and for length of dental arch from M_1 to I_1 ($= L$) and length in per cent of width of dental arch** $\left(= \frac{L \times 100}{B_2}\right)$.

σ_i is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{2n}}$, where d is the difference between two measurements of the same individual. M = arithmetical mean of the measures in both determinations.

Measure	Jaw	No. of double determinations	σ_i	σ_i in per cent of M
B_1	upper	37	0.16	0.47
	lower	39	0.15	0.59
B_2	upper	38	0.25	0.53
	lower	38	0.16	0.47
L	upper	38	0.25	0.81
	lower	37	0.19	0.66
$\frac{L \times 100}{B_2}$	upper	39	0.57	—
	lower	38	0.69	—

jaw and the over-bite was estimated with an accuracy of 0.5 mm.

6. The measurement of the occlusion in *the vertical plane* was obtained as the mean value of the two vertical distances between the edges of the medial incisors in the upper and lower jaw. The same spatula as used for measuring the sagittal overbite, was placed on the plaster-models against the edge of the medial incisors in the upper jaw parallel with the occlusal plane; and with its point a fine mark was scratched on the facial surface of the incisors in the lower jaw (fig. 8). The vertical over-bite was then measured with an accuracy of 0.1 mm. In the case of open-bite, the distance in the vertical plane between the edges of the front teeth in the upper and lower jaw was measured directly on the model, and this distance was given a negative indication.

Table 15. **The error of measurement in mm (the standard error of a single determination, σ_i) for different characters.**

σ_i is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{2n}}$, where d is the difference between two measurements of the same individual. M = arithmetic mean of the measures in both determinations.

Measure	No. of double determinations	σ_i	σ_i in per cent of M
Inclination of upper medial incisors	40	0.16[1]	—
Height of palatal vault	37	0.19	1.10
Mesio-distal occlusion at M_1 left	36	0.36	—
Mesio-distal occlusion at M_1 right	35	0.34	—
Mesio-distal occlusion at M_1 average	35	0.29	—
Sagittal overbite	40	0.27	—
Vertical overbite	37	0.22	—
Differ. between the jaws in arch-width at P_1	37	0.22	—
Differ. between the jaws in arch-width at M_1	36	0.32	—

[1] 1 mm = appr. 6.3°.

7. The relationship between the jaws in the *transversal plane* was found by subtracting from the values of the width of the upper jaw (B_1 and B_2) the corresponding values of the dental arch of the lower jaw.

The errors of measurements have been determined by help of double determinations. The standard error of a single determination for the different measurements are given in tables 12—15.

CHAPTER III.

STATISTICAL METHODS USED

In our literature different methods are used, based on quantitative observations on twins, which determine the significance of heredity as compared to that of the environment.

In the Anglo-Saxon literature calculations of the correlation has earlier been employed particularly by writers belonging to the biometrical school (such as *Stocks* 1930, *Hogben* 1933, *Newman—Freeman—Holzinger* 1937). Thus the correlation is calculated between identical and fraternal co-twins according to Bravais—Pearson, and through the differences between the correlation coefficients one gets a conception of the significance of heredity in relation to that of environment. Where a strong correlation exists, in the case of identical twins, and a relatively weak one of the fraternal, the conclusion which can be drawn is that the hereditary factors have a predominating significance, while an insignificant difference of correlation between identical and fraternal twins points to the fact that the environment is above all the most important factor. Correlation coefficients give, however, no concrete idea, and so in the later literature the employment of these coefficients has been little used.

Dahlberg (1926) has introduced the following view point and formulae when analysing twins. The variability in the identical and fraternal twins is studied firstly by determining the standard deviation for the differences within the pairs for which the following formula is applied:

$$\sigma_0 = \sqrt{\frac{\Sigma d^2}{n}},$$

where d is the difference between the co-twins, and n the number of pairs. In cases with bilateral characters the same formula can be applied in order to study the variability in the individual; then d is the difference between the left and right side, and n the number of individuals. If a systematic difference exists between the left and right side the formula:

$$\sigma_D = \sqrt{\frac{\Sigma d^2}{n} - b^2}$$

is applied instead, where b is the arithmetic mean for the differences between the left and right side.

Dahlberg divides the total variability as regards heredity and environment according to the following methods. If the variation caused by environment is independant of the variation caused by heredity and is further independant of that as caused by error of measurement, then these are combined to form the following formula:

$$\sigma_{1+2+3} = \sqrt{\sigma_1^2 + \sigma_2^2 + \sigma_3^2} \quad \ldots\ldots\ldots \quad (1)$$

where σ_{1+2+3} is the standard deviation of the fraternal twins, σ_1 is the standard deviation of environment, σ_2 is the standard deviation of heredity and σ_3 is the standard error of the method.

The standard deviation of identical twins is given through the formula:

$$\sigma_{1+3} = \sqrt{\sigma_1^2 + \sigma_3^2} \quad \ldots\ldots\ldots\ldots \quad (2)$$

where σ_{1+3} is the standard deviation of the identical twins.

σ_{1+2+3}, σ_{1+3} and σ_3 are obtained through the formula:

$$\sigma = \sqrt{\frac{\Sigma d^2}{2n}} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (3)$$

where d is the difference between fraternal co-twins, be-

tween identical co-twins, and between the double determinations of the same individual respectively, and n is the number of twin-pairs and double determinations respectively.

Through combining the formulae 1, 2, and 3 the quotient between heredity and environment is obtained:

$$\frac{\text{heredity}}{\text{environment}} = \frac{\sigma_2}{\sigma_1} = \sqrt{\frac{\sigma^2{}_{1+2}}{\sigma_1{}^2} - 1}\,*$$

Calculations carried out on twins as to heredity and environment show conditions within the families, and cannot therefore directly be transferred to the population. One has to reckon with that the environmental variation between twins is less since they are brought up in comparatively similar environment. Furthermore, variation depending on heredity is less as they have the same parents, which fact limits the possibility for variation. (*Dahlberg* 1942 and *G. Dahlberg* and *B. Dahlberg* 1942). The difference between a pair of individuals selected by chance from the population is also greater than between two brothers or sisters, which *Dahlberg* (1942) showed for certain anthropological characteristics and *Norinder* (1946) for their handwriting. It is therefore necessary to investigate whether the same relationship also exists in the characteristics investigated in this work. Of course one can employ the total variation of a twin-material as a measurement of the variation within the population. As a correlation exists between twins, the distribution is then most simply cal-

* In Germany an incorrect formula presented by *Lenz-v. Verschuer* (1928) was previously used, based on the mean percent deviation between twins introduced by *v. Verschuer* (1925). Afterwards this formula was improved firstly by *Lenz* (1935) himself and later by *Luxemburger* (1940), and now it corresponds completely to Dahlberg's formula except that the mean deviation is employed instead of the standard deviation. As the mean deviation is not a suitable measurement of dispersion in statistical calculation Dahlberg's formula ought to be used.

culated by using only one twin in each pair. The quotient which is calculated between heredity and environment, may however be correct, namely if hereditary and environmental effects are equally reduced. There is naturally no certainty that this is the case, which is why such quotients must be treated with some caution. It is, of course, interesting to know what degree of uncertainty is the consequence of these circumstances. This can be decided by calculating the maximum and minimum values for the quotient between heredity and environment. Thus the maximum value is obtained by substituting the standard deviation for the fraternal twins (σ_{1+2}) with the standard deviation for the population (σ_{pop}). The minimum value is obtained by substituting the standard deviation for the identical twins (σ_1) with

$$\sqrt{\sigma_1^2 + (\sigma^2_{pop} - \sigma^2_{1+2})},$$

by means of which the dispersion differences between the population and fraternal twins is presupposed as being conditioned only by environment. The margin of uncertainty calculated in this way, is among other things, dependent on the heredity-environment quotient in twins, so that it becomes greater with a high quotient than with a low one. Thus, if the quotient is 1, 2 and 3 respectively, and the standard deviation for the population 1.4 times greater than that of the fraternal twins (the average relation for the tooth-breath), the maximum values become 1.4, 3.0 and 4.6, and the minimum values 0.6, 0.8 and 0.9; the difference between the former and the latter being 0.8, 2.2 and 3.7.

One further reservation must be made with respect to some *internal factors* showing random variation between left and right side. Professor Dahlberg has pointed out to me, that such factors might cause a difference between the left and right side of an individual, and naturally, also differences between identical pairs of twins.

This is particularly true of characters having a low penetrability. According to the above mentioned formulae, such differences will be regarded as being conditioned by environment, but it would be more appropriate to consider them accidental, without ascribing them to heredity or environment. This distinction is of such an importance, that an alteration in the usual terminology seems justified. Consequently, in this work a distinction will be made between *heredity* and *non-heredity*, and not between heredity and environment. Dahlberg's viewpoint will be later explained in greater detail (cf. page 92).

Even such a demarkation is, however, made difficult in *genotypic asymmetries* (compare *Dahlberg* 1926, 1930, 1943) with definite orientation in the lateral direction (e. g. location of the intestines, right and left handedness and the direction of the hair-whirl). Oberservations on twins sometimes show a certain tendency towards mirror-reflection in identical twin-pairs, especially investigated as to right and left handedness (compare *Dahlberg* 1926, *v. Verschuer* 1933, *Norinder* 1946). This indicates, that hereditarily conditioned differences might occur between identical twins, and these might then even be of another type than mirror-images. If, namely, differences conditioned by heredity exist between left and right sides, it is natural that such differences should also be found between identical co-twins, who might be compared with two halves of the body separated during development.

Practically speaking, it is often difficult to distinguish between those differences which depend on external environments, internal accidental factors, or on actual genotypic asymmetries. Consequently, if appreciable asymmetry formation occurs for one character, the results must then always be treated with some caution, because they might show too strong an effect for non-genetic factors as compared to the genetic factors.

A measurement of the variability according to unilaterally affecting factors, can be obtained for characters which

can be measured on both sides of the median line. For such characters *the asymmetric variability* can be calculated according to the formula:

$$\sigma_{1:1} = \sqrt{\sigma^2_{0,a} - \sigma^2_m} \cdot \frac{1}{\sqrt{2}}$$

where $\sigma_{0,a}$ is the standard deviation for the differences between the left and right side, and σ_m for the differences between double-measurements.

That variability which is obtained by substracting the asymmetric variability from the non-genetic variability can be termed *environmental variability,* and this should depend essentially on symmetrically affecting environmental factors, but possibly also on internal random factors active during the early embryonic stage. This variability is obtained according to the formula:

$$\sigma_{1:2} = \sqrt{\sigma^2_{0,id} - \sigma^2_{0,a}} \cdot \frac{1}{\sqrt{2}}$$

where $\sigma_{0,id}$ is the standard deviation for differences within identical twin-pairs, and $\sigma_{0,a}$ the standard deviation for differences between the left and right side.

The standard errors for the statistical expressions mentioned above has been calculated according to the formulae:

$$\varepsilon(\sigma_0) = \frac{\sigma_0}{\sqrt{2_n}}$$

$$\varepsilon(\sigma_1) = \sqrt{\varepsilon(\sigma_{0,id})^2 + \varepsilon(\sigma_m)^2} \cdot \frac{1}{\sqrt{2}}$$

$$\varepsilon\left(\frac{\sigma_2}{\sigma_1}\right) = \sqrt{\frac{\varepsilon(\sigma_2)^2}{\sigma_1^2} + \frac{\sigma_2^2}{\sigma_1^4} \cdot \varepsilon(\sigma_1)^2}$$

The standard error for σ_D, σ_m and σ_s has been calculated according to the first of these formulae, and the standard errors for σ_2, $\sigma_{1:1}$ and $\sigma_{1:2}$ analogically to the second.

CHAPTER IV.

CASES INVESTIGATED

The cases of the present work comprise 202 pairs of twins of the same sex, namely 100 identical and 102 fraternal pairs. The addresses of these twins have mainly been received from schools in Stockholm. In addition, 54 addresses were given to me by Ph. D. *Yngve Norinder,* and I take the opportunity of thanking Dr. Norinder for his help in this respect, as well as for the valuable information I have obtained from him about these twins. The reason why identical twins are so well represented is that when procuring the twins' addresses I endeavoured to get an equal representation of identical and fraternal twins.

When distinguishing between identical and fraternal twins I have not been able to utilise the type of the afterbirth, because information about this has only been obtainable in a few exceptional cases (besides it is an object of discussion to which extent one can depend upon such information). Therefore it became necessary to base the diagnosis on the similarity of the twins. I have used the same method as *Dahlberg* (1926) and *Norinder* (1946), i. e. the diagnosis was made according to the general similarity. The structure of the ears and the colour of the eyes were studied separately, because these are not of particular importance to the general similarity. Of course, this method may cause a few mistakes, particularly in those rare cases in which fraternal twins may be very similar. Dahlberg has pointed out that this is especially the case as regards younger twins, who have not had time to finish the differentiation of their appearance. In this connection Dahlberg also reported one case in which two adult

brothers, with a year's difference in age, were so similar that they caused confusion as to their identity. This example illustrates the risk taken when making a diagnosis on twins based on their general similarity.

The twins who were registered as identical were those who first and foremost, were similar according to the above-mentioned norm (82 pairs). One pair out of these showed a dissimilarity as to the colour of their eyes, namely, one having a brown spot in a blue eye. This dissimilarity is probably a genotypic asymmetry and should, therefore, not be considered as a sign of dizygosity. To the identical twins, 5 pairs were also included who, according to information, were generally not mistaken for eachother, but between whom I could not distinguish during examination, and who were also similar as regards the structure of their ears as well as the colour of their eyes. One pair of identical twins wore eye-prosthesis, but the diagnosis could, nevertheless be made, because of the similar structure of their ears, and the extreme external similarity which generally caused confusion as to their identity. In the identical twins 6 pairs have also been included who were confusingly similar; they had, however, slight dissimilarities in the structure of their ears but the same coloured eyes. Besides these, 3 pairs were included who could not be examined at the same time but who, according to information, were usually mistaken for eachother by friends and teachers, and who, also according to information, had exactly the same coloured eyes. The diagnosis of one of these 3 pairs was supported by photographs showing a striking similarity. Two pairs of identical twins were also included whom I had examined before the actual selection of the material, and about whom no other information was given than that they were usually mistaken for eachother. Finally one pair of identical twins was included who stated that they were usually not mistaken for eachother by relatives and friends. They seemed, however, difficult to distinguish between

when I examined them, and furthermore had same coloured eyes, but slight dissimilarities in the structure of their ears. Norinder who had previously examined the same pair, considered them as being identical because of the information he obtained about their being mistaken for eachother in school, and because of the examination he made 5 years prior to mine. The case is naturally doubtful. It is possible that here we are dealing with fraternal twins who, little by little, grow more dissimilar. At present, however, predominant reasons should indicate that they are identical.*

The pairs of twins who were dissimilar according to the abovementioned norms have been registered as fraternal twins.

A comparison between Norinders diagnosis and mine might be of interest. Out of 48 pairs who were examined completely independently by Norinder and me with an interval of approximately 5 years, the same diagnosis had been made for 45 pairs, 35 fraternal and 10 identical, while 3 pairs were given a different diagnosis. One of the pairs has already been discussed. Norinder had registered the remaining 2 pairs as possible fraternal twins while, according to my determination, they were confusingly similar and, therefore, identical.

The distribution of the identical and fraternal pairs of twins with respect to age and sex appears in table 16. As can be seen from the table, the difference in the distribution is insignificant as regards the size of the material. That mainly young persons have been investigated is because it is easier to procure such material for examination.

I have tried to procure, first and foremost, twins not under 12 years of age. A few younger cases were, however, included. No selection from an odontological viewpoint was

* If one puts the doubtful cases into one special group, the identical twins will consist of extremely similar, and the fraternal of extremely dissimilar pairs of twins. The result of such a division becomes in other words misleading in principle.

Table 16. **The total number of identical and fraternal twin pairs distributed according to age and sex.**

Age, years	Identical twin pairs			Fraternal twin pairs		
	Males	Females	Both sexes	Males	Females	Both sexes
8	1	—	1	—	—	—
9	—	1	1	—	1	1
10	—	2	2	1	—	1
11	—	1	1	2	—	2
12	5	6	11	6	6	12
13	6	3	9	7	14	21
14	7	8	15	7	13	20
15	2	4	6	13	5	18
16	5	7	12	3	4	7
17	2	—	2	1	4	5
18	1	2	3	3	3	6
19	2	3	5	1	—	1
20	2	1	3	1	—	1
21	—	3	3	—	1	1
22	1	—	1	1	1	2
23	—	1	1	—	1	1
24	—	4	4	—	—	—
25	1	3	4	—	—	—
26	—	2	2	1	—	1
27	—	1	1	—	—	—
28	—	1	1	1	—	1
29	2	1	3	—	—	—
30	—	—	—	—	1	1
31	1	3	4	—	—	—
32	1	1	2	—	—	—
33	—	1	1	—	—	—
34	—	—	—	—	—	—
35	—	—	—	—	—	—
36	—	1	1	—	—	—
37	—	—	—	—	—	—
38	—	—	—	—	—	—
39	—	—	—	—	—	—
40	1	—	1	—	—	—
Total	40	60	100	48	54	102
Arithmetical mean	17.3 ± 1.1	18.9 ± 1.0	18.3 ± 0.72	15.3 ± 0.76	14.8 ± 0.39	14.9 ± 0.41
First quartile..	13.7	14.3	14.0	13.5	13.5	13.5
Median	15.5	16.8	16.4	15.1	14.5	14.7
Third quartile	19.6	24.8	23.5	16.3	16.6	16.3

made apart from the fact that 6 pairs of twins with malocclusion were received from the orthodontic departments of the Eastman-clinic, and the Dental School in Stockholm.

Besides the twins, an average-material consisting of 13 years old Council School children, 140 boys and 87 girls, was also used for the determination of certain differences between the left and right side as regards the tooth-size.

CHAPTER V.

THE CASES FROM A REPRESENTATIVE POINT OF VIEW

It is of importance to the following examination that the material is representative. Fortunately there is a possibility of determining this, viz. the tooth-breadth and some characters of the tooth position, because comparable examinations have been made previously on average-material. Tables 17—21 show mean and standard deviations of the previously examined material, and for the twins in the size of certain teeth (I_1, I_2 and C in the upper jaw), the width and length of the upper dental arch, the height of the palatal vault, the size of the over bite (vertical and sagittal) and the sagittal occlusion between the upper and lower M_1. The twin-figures were calculated on one twin out of each pair; as no differences were found between identical and fraternal twins, and as they are not probable either, the twin-figures have been conjoined.

The figures on the whole agree well within the different materials (*Nordlund*, 1918, *A. Lundström*, 1943, 1944, 1946 and 1948, *Seipel*, 1946 and *Björk*, 1947). Certain differences as to the mean values, it is true, can be found for several characters but they are so small that they must be considered as having no noteworthy importance. Thus Seipel's figures as regards the tooth size are somewhat higher than those of the author (0.2 à 0.3 mm.), and, furthermore, those figures for the width of the dental arch found by Nordlund differ with an approximately 2 mm. broader dental arch at M_1 than do other comparable values. Björk's and Seipel's overbite figures are also somewhat

Table 17. **Mean, M, and standard deviation, σ, in the tooth-breadth of I_1, I_2 and C in the upper jaw according to different authors.**

Tooth	Sex	*Lundström* (1944) Left side	*Lundström* (1944) Right side	*Seipel* (1946)	Twins
		Mean: $M \pm \varepsilon(M)$			
I_1	M	8.7 ± 0.04	8.7 ± 0.04	8.8 ± 0.03	8.7 ± 0.06
	F	8.6 ± 0.05	8.5 ± 0.05	8.6 ± 0.02	8.4 ± 0.05
I_2	M	6.7 ± 0.04	6.6 ± 0.04	6.8 ± 0.03	6.8 ± 0.07
	F	6.6 ± 0.05	6.5 ± 0.06	6.6 ± 0.03	6.5 ± 0.06
C	M	7.8 ± 0.04	7.8 ± 0.03	8.1 ± 0.02	7.8 ± 0.04
	F	7.6 ± 0.04	7.6 ± 0.04	7.7 ± 0.02	7.5 ± 0.04
		Standard deviation: $\sigma \pm \varepsilon(\sigma)$			
I_1	M	0.52 ± 0.03	0.53 ± 0.03	0.55 ± 0.02	0.49 ± 0.04
	F	0.48 ± 0.03	0.47 ± 0.03	0.53 ± 0.02	0.48 ± 0.03
I_2	M	0.52 ± 0.03	0.58 ± 0.03	0.60 ± 0.02	0.59 ± 0.05
	F	0.57 ± 0.04	0.58 ± 0.04	0.57 ± 0.02	0.60 ± 0.04
C	M	0.41 ± 0.02	0.43 ± 0.02	0.46 ± 0.01	0.38 ± 0.03
	F	0.37 ± 0.03	0.37 ± 0.03	0.41 ± 0.01	0.38 ± 0.03

higher than those of the author. These deviations might naturally be true, and may depend upon differences in the materials, which were collected from various regions. It might also be that the differences are caused by the fact that the measurements were made by different persons, or that different measuring methods were used. It is natural, for instance, that Björk's measurements of the overbite on X-ray profiles must give results somewhat differing from those measurements made directly in the mouth, or on a model.

As to the standard deviations, which are of greater importance to the present examination, there is, on the whole, a good agreement between the different figures. Consequently one can reckon with the fact that the twin material represents the population in general fairly well as regards the examined characters.

Table 18. **Mean, M, and standard deviation, σ, (in mm) of the arch width in the upper jaw at P_1 and M_1 according to different authors.**

Author, year	Material Age, years	With (w) or without (o) missing teeth	Arch width at P_1			Arch width at M_1		
			No.	$M \pm \varepsilon(M)$	σ	No.	$M \pm \varepsilon(M)$	σ
				Males				
Nordlund, 1918...	Conscripts	—	—	—	—	99	48.8 ± 0.30	3.8
Seipel, 1946.....	13	o	214	35.7 ± 0.19	2.7	215	46.4 ± 0.19	2.8
» »	21	o	57	36.1 ± 0.31	2.3	55	46.6 ± 0.45	3.4
Lundström, 1946	13	—	112	36.7 ± 0.23	2.4	111	47.4 ± 0.24	2.5
» »	Adults	—	48	34.9 ± 0.44	3.0	41	47.3 ± 0.59	3.8
	Twins:[3]							
Lundström, 1948	12—15	o	46	34.9 ± 0.45	3.0	47	47.0 ± 0.48	3.3
» »	16—40	o	25	34.6 ± 0.46	2.3	25	46.3 ± 0.68	3.4
» »	12—40	o	71	31.8 ± 0.33	2.8	72	46.8 ± 0.39	3.3
» »	12—40	w[1]	12	33.9	.	16	44.6 ± 0.82	3.3
» »	12—40	w[2]	17	35.3 ± 0.73	3.0	—	-	—
				Females				
Seipel, 1946.....	13	o	204	34.3 ± 0.16	2.3	203	44.9 ± 0.19	2.7
» »	21	o	142	34.3 ± 0.18	2.2	135	44.9 ± 0.24	2.8
Lundström, 1946	13	—	67	34.2 ± 0.34	2.8	66	46.0 ± 0.34	2.8
	Twins:[3]							
Lundström, 1948	12—15	o	47	33.7 ± 0.33	2.2	48	45.2 ± 0.40	2.7
» »	16—40	o	36	33.7 ± 0.38	2.3	35	45.3 ± 0.46	2.7
» »	12—40	o	83	33.7 ± 0.24	2.2	83	45.2 ± 0.30	2.7
» »	12—40	w[1]	21	32.8 ± 0.69	3.2	23	43.2 ± 0.72	3.4
	12—40	w[2]	35	34.1 ± 0.33	2.0	—	—	—

[1] $(I_1 - P_2)$ [2] (M_1)

[3] One twin in each pair.

Possible sex and age differences in the dispersion are of importance to the calculations made on twins, as such differences might effect the results due to the somewhat different age and sex distribution of the identical and fraternal twins. As the teeth and jaws of the males are

Table 19. **Mean, M, and standard deviation, σ, (in mm) of the length of the dental arch and of the height of the palatal vault according to different investigations.**

Author, year	Material Age, years	With (w) or without (o) missing teeth	Length of dent. arch			Height of pal. vault		
			No.	$M \pm \varepsilon(M)$	σ	No.	$M \pm \varepsilon(M)$	σ
			Males					
Lundström, 1946	13	—	112	31.6 ± 0.22	2.3	121	17.2 ± 0.14	1.6
	Adults	—	—	—	—	44	19.9 ± 0.32	2.1
	Twins:[2]							
Lundström, 1948	12—15	o	47	32.3 ± 0.36	2.5	47	17.3 ± 0.34	2.4
	16—40	o	25	30.8 ± 0.42	2.1	24	19.6 ± 0.37	1.8
	12—40	o	72	31.7 ± 0.29	2.4	71	18.1 ± 0.29	2.4
»	12—40	w[1]	16	28.4 ± 0.54	2.2	15	17.3 ± 0.67	2.6
			Females					
Lundström, 1946	13	—	63	30.5 ± 0.28	2.2	65	17.5 ± 0.24	2.0
	Twins:[2]							
Lundström, 1948	12—15	o	48	31.1 ± 0.28	1.9	48	16.7 ± 0.27	1.9
» »	16—40	o	35	30.2 ± 0.33	2.0	35	18.1 ± 0.35	2.1
»	12—40	o	83	30.7 ± 0.21	2.0	83	17.3 ± 0.23	2.1
»	12—40	w[1]	24	29.2 ± 0.53	2.6	24	17.3 ± 0.44	2.2

[1] $(I_1 - P_2)$.

[2] One twin in each pair.

larger than those of the females the dispersion, measured in absolute measurements, should also be somewhat greater for men than for women. Previous examinations of the population (*A. Lundström,* 1944, *Seipel,* 1946) show, however, that only very insignificant sex differences in the standard deviation occur in the tooth-size. Thus in Seipel's exceedingly comprehensive material (approximately 500 males and 500 females with measurements of all their teeth) no significant differences are to be found, and only one probable difference existing (for the upper canine = $+0.05 \pm 0.02$ mm.).

As regards the size of the jaws and their relation to

Table 20. **Mean, M, and standard deviation, σ, (in mm) of the sagittal molar occlusion on left and right side according to different authors. Cases of both sexes.**

Author, year	Material Age, years	With (w) or (and) without (o) missing teeth	Jaw	Sagittal molar occlusion			
				Side	No.	$M \pm \varepsilon(M)$	σ
Lundström, 1943	13	o + w	—	l	186	− 0.06 ± 0.16	2.10
» »	13	o + w	—	r	184	− 0.43 ± 0.16	2.08
Björk, 1947	12	o + w	—	r	293	− 1.70 ± 0.12[1]	2.11
» »	21—22	o + w	—	r	150	− 2.54 ± 0.26[1]	3.22
	Twins[2]						
Lundström, 1948	12—15	o	—	l	79	− 0.16 ± 0.27	2.42
» »	12—15	o	—	r	79	− 0.51 ± 0.24	2.12
»	16—40	o	—	l	45	− 0.46 ± 0.33	2.21
»	16—40	o	—	r	43	− 0.59 ± 0.38	2.47
»	12—40	o	—	l	124	− 0.27 ± 0.21	2.34
»	12—40	o	—	r	122	− 0.54 ± 0.20	2.24
»	12—40	w	u	l	21	− 1.06 ± 0.42	1.94
»	12—40	w	u	r	21	− 1.82 ± 0.63	2.88
	12—40	w	l	l	21	+ 1.93 ± 0.50	2.29
	12—40	w	l	r	22	+ 0.59 ± 0.30	1.39
»	12—40	w	u + l	l	19	− 0.52 ± 0.60	2.62
»	12—40	w	u + l	r	18	− 1.07 ± 0.64	2.72

[1] The difference between the mean of Björks' values and the other values depends on different measuring points.

[2] One twin in each pair.

eachother, the corresponding differences also seem to be relatively small with provable differences for only a few characters. Seipel found a significantly, or a probably greater dispersion for the males than for the females as regards the width of the dental arch at M_1 in the upper jaw (difference = +1.1±0.34 mm.), and at P_1 in the lower jaw (= +0.4±0.17 mm.). In the twin-material (table 22) the same circumstance seems to apply to the length of the dental arch in the lower jaw (= +0.9±0.28 mm.), and in

Table 21. **Mean, M, and standard deviation, σ, (in mm) of the vertical and the sagittal overbite at I_1 according to different authors.**

Author, year	Material Age, years	With (w) or (and) without (o) missing teeth	Vertical overbite			Sagittal overbite		
			No.	$M \pm \varepsilon(M)$	σ	No.	$M \pm \varepsilon(M)$	σ
				Males				
Seipel, 1946	13	o	211	3.73 ± 0.12	—	211	3.83 ± 0.15	—
.....	13	o + w	255	3.67 ± 0.09	—	255	3.84 ± 0.14	—
.....	21	o	38	3.06 ± 0.35	—	38	2.89 ± 0.30	—
»	21	o + w	243	3.20 ± 0.14	—	244	2.52 ± 0.12	—
Lundström, 1946	Adults	o + w	52	3.3 ± 0.31	2.2	52	2.8 ± 0.22	1.6
Björk, 1947	12	o + w	322	2.67 ± 0.10	1.75	322	4.17 ± 0.12	2.18
»	21—22	o + w	281	2.02 ± 0.12	1.97	281	2.98 ± 0.17	2.92
				Females				
Seipel, 1946	13	o	200	3.41 ± 0.12	—	200	3.47 ± 0.12	—
» »	13	o + w	240	3.43 ± 0.11	—	245	3.46 ± 0.11	—
» »	21	o	99	3.34 ± 0.20	—	99	3.30 ± 0.20	—
» »	21	o + w	249	3.46 ± 0.13	—	250	3.41 ± 0.13	—
				Both sexes				
Lundström, 1943	13 Twins[4]	o + w	222	2.85 ± 0.09	1.39	224	2.91 ± 0.12	1.75
Lundström, 1948	12—15	o	84	2.72 ± 0.18	1.65	85	3.38 ± 0.21	1.95
»	16—40	o	47	2.21 ± 0.22	1.54	48	3.27 ± 0.32	2.20
»	12—40	o	131	2.53 ± 0.14	1.63	133	3.34 ± 0.18	2.04
»	12—40	w[1]	28	2.22 ± 0.27	1.42	28	2.59 ± 0.25	1.30
»	12—40	w[2]	34	2.53 ± 0.36	2.12	36	3.04 ± 0.27	1.61
	12—40	w[3]	65	2.36 ± 0.22	1.74	67	2.86 ± 0.22	1.77

[1] Upper jaw. [2] Lower jaw. [3] Both jaws.
[4] One twin in each pair.

the upper jaw (= +0.6±0.30 mm.) and the width of the dental arch at P_1 in the same jaw (= +0.8±0.39 mm.).

It is unnecessary to reckon with any change in age in the dispersion of the tooth-sizes, as any noteworthy changes of the tooth-breadth due to age do not occur (*Seipel*, 1946). The dispersion as to the size of the jaws and their relation to eachother seems also to be on the whole unchanged after

Table 22. **Difference between the sexes according to the standard deviation, σ, (in mm and in per cent) in different characters. Twins without missing teeth, 12—15 years of age.**

σ is calculated according to the formula $\sqrt{\frac{\Sigma a^2}{n}}$, where a is the deviation from the mean and n the number of individuals (one in each pair).

Character	Jaw	Males	Females	Diff. betw. M and F
		$\sigma \pm \varepsilon(\sigma)$	$\sigma \pm \varepsilon(\sigma)$	$D \pm \varepsilon(D)$
Arch-space, $M_1 - M_1$ (in mm)	u	5.0 ± 0.51	4.2 ± 0.43	+ 0.8 ± 0.67
	l	4.2 ± 0.45	3.3 ± 0.34	+ 0.9 ± 0.56
Width of dent. arch at P_1 (in mm)	u	3.0 ± 0.31	2.2 ± 0.23	+ 0.8 ± 0.39
	l	2.0 ± 0.22	2.0 ± 0.20	± 0 ± 0.30
» » » » » M_1 (in mm)	u	3.3 ± 0.34	2.7 ± 0.28	+ 0.6 ± 0.44
	l	2.4 ± 0.26	2.7 ± 0.28	— 0.3 ± 0.38
Length of dent. arch (in mm)	u	2.5 ± 0.25	1.9 ± 0.16	+ 0.6 ± 0.30
	l	2.3 ± 0.24	1.4 ± 0.15	+ 0.9 ± 0.28
Length in per cent of width at M_1	u	6.2 ± 0.64	5.9 ± 0.60	+ 0.3 ± 0.88
	l	9.0 ± 0.96	9.1 ± 0.93	— 0.1 ± 1.34
Inclin. of medial incisors (in mm)[1] ...	u	0.7 ± 0.07	0.8 ± 0.08	— 0.1 ± 0.11
Height of palatal vault (in mm)	u	2.4 ± 0.24	1.9 ± 0.19	+ 0.5 ± 0.31
Sag. molaroccl. (both sides, in mm	—	1.9 ± 0.22	2.3 ± 0.26	— 0.4 ± 0.34
Sagittal overbite (in mm)	—	2.1 ± 0.22	1.7 ± 0.19	+ 0.4 ± 0.29
Vertical overbite (in mm)	—	1.7 ± 0.19	1.6 ± 0.17	+ 0.1 ± 0.26
Diff. in width betw. u. and l. jaw at P_1 (in mm)	—	2.5 ± 0.28	1.9 ± 0.21	+ 0.6 ± 0.35
Diff. in width betw. u. and l. jaw » M_1 (in mm)	—	2.6 ± 0.28	2.3 ± 0.26	+ 0.3 ± 0.38

[1] 1 mm = 6.3°.

12 years of age (*Seipel*, 1946, *A. Lundström*, 1946, *Björk*, 1947). In Björk's material there exists, however, one significant difference in the standard deviations for the sagittal occlusion of the jaws between 20—21 years and 12 years of age (at the medial incisors = +0.74±0.15 mm. and at the first molars = +1.11±0.21 mm.).

It is evident that the differences in the dispersion between the sexes or age-groups are not great, and it is there-

fore not probable that they will effect the results, especially as the dissimilarity in sex and age distribution is moderate between identical and fraternal twins (see table 16, page 74).

It is of far greater importance to investigate if the differences between the twins obtained can be said to be representative for the population.

As shown by *Dahlberg* (1926), it is possible to calculate from the differences between fraternal twins that variability, which should exist in a population in which heredity varies equally as much as it does in fraternal twins, and in which the environment also has the same variability as exists within the pairs of twins. It is obvious that the actual variability existing in the population should, in both respects, be greater. The question is: how great can the difference become? Such a comparison has been made previously by *Dahlberg* (1943) as to anthropological characters, and he found that the calculated variability is somewhat smaller than the actual one characterising the population.

The dispersion of the tooth-size in fraternal twins and in the population (calculated on one twin out of each pair) appears in table 23, which shows that the population constantly exhibits somewhat higher standard deviations (average 1.4 times as great) than the fraternal twins, and that the differences for several teeth are significant (this is true as regards upper I_2 in both sexes, and upper C in females, and the lower I_1, I_2, C and P_1 in the females). The differences are also most probable (between 2½ and 3 times their mean error) for upper P_1 in both sexes, for upper P_2 in the females and for lower C in the males. If instead, the differences are determined between the fraternal twins and *Seipel*'s material (see page 77) the difference, dependent on the size of this, is significant for 14 teeth, and almost significant for 3 teeth out of 24. On an average Seipel's material also shows standard deviations 1.4 times greater than those obtained for fraternal twins.

Table 23. **Difference and ratio between population and fraternal twins of the standard deviation, σ, of the tooth-breadth (mesio-distal width in mm).**

σ of population is calculated according to the formula $\sqrt{\frac{\Sigma a^2}{n}}$, where a is the deviation from the mean and n the number of individuals (one in each pair),

σ of fraternal twins is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{2n}}$ where d is the difference between the co-twins and n the number of twin pairs.

Tooth	Sex	Fraternal twins (a) $\sigma \pm \varepsilon(\sigma)$	Population (b) $\sigma \pm \varepsilon(\sigma)$	Difference between (b) and (a) $D \pm \varepsilon(D)$	$\frac{\sigma_{(pop.)}}{\sigma_{(frat.tw.)}}$
		Upper jaw			
I_1	M	0.41 ± 0.04	0.49 ± 0.04	+ 0.08 ± 0.059	1.2
	F	0.33 ± 0.03	0.48 ± 0.03	+ 0.15 ± 0.047	1.5
I_2	M	0.40 ± 0.04	0.59 ± 0.05	+ 0.19 ± 0.062	1.5
	F	0.41 ± 0.04	0.60 ± 0.04	+ 0.19 ± 0.058	1.5
C	M	0.33 ± 0.04	0.38 ± 0.03	+ 0.05 ± 0.048	1.2
	F	0.22 ± 0.02	0.38 ± 0.03	+ 0.16 ± 0.035	1.7
P_1	M	0.27 ± 0.03	0.41 ± 0.04	+ 0.14 ± 0.048	1.5
	F	0.33 ± 0.04	0.46 ± 0.04	+ 0.13 ± 0.052	1.4
P_2	M	0.32 ± 0.04	0.35 ± 0.03	+ 0.03 ± 0.053	1.1
	F	0.28 ± 0.04	0.41 ± 0.03	+ 0.13 ± 0.048	1.5
M_1	M	0.38 ± 0.06	0.50 ± 0.05	+ 0.12 ± 0.074	1.3
	F	0.35 ± 0.05	0.49 ± 0.04	+ 0.14 ± 0.068	1.4
		Lower jaw			
I_1	M	0.25 ± 0.03	0.34 ± 0.03	+ 0.09 ± 0.039	1.4
	F	0.20 ± 0.02	0.31 ± 0.02	+ 0.11 ± 0.029	1.6
I_2	M	0.32 ± 0.03	0.39 ± 0.03	+ 0.07 ± 0.047	1.2
	F	0.25 ± 0.02	0.35 ± 0.02	+ 0.10 ± 0.033	1.4
C	M	0.27 ± 0.03	0.37 ± 0 03	+ 0.10 ± 0.040	1.4
	F	0.20 ± 0.02	0.35 ± 0.02	+ 0.15 ± 0.031	1.8
P_1	M	0.31 ± 0.04	0.38 ± 0 03	+ 0.07 ± 0.047	1.2
	F	0.26 ± 0.03	0.40 ± 0.03	+ 0.14 ± 0 040	1.5
P_2	M	0.26 ± 0.04	0.37 ± 0.03	+ 0.11 ± 0.049	1.4
	F	0.35 ± 0.04	0.42 ± 0.03	+ 0.07 ± 0.050	1.2
M_1	M	0.51 ± 0.08	0.67 ± 0.06	+ 0.16 ± 0.100	1.3
	F	0.39 ± 0.05	0.50 ± 0.04	+ 0.11 ± 0.068	1.3

Table 24. **Difference and ratio between population and fraternal twins of the standard deviation, σ, (in mm and in per cent) in different characters. Cases of both sexes without missing teeth.**

σ of population is calculated according to the formula $\sqrt{\frac{\Sigma a^2}{n}}$, where a is the deviation from the mean and n the number of individuals (one in each pair).

σ of fraternal twins is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{2n}}$, where d is the difference between the co-twins and n the number of twin pairs.

Character	Jaw	Fraternal twins (a) $\sigma \pm \varepsilon(\sigma)$	Population (b) $\sigma \pm \varepsilon(\sigma)$	Diff. between (b) and (a) $D \pm \varepsilon(D)$	$\frac{\sigma_{(pop.)}}{\sigma_{(frat.tw.)}}$
Arch-space, $M_1 - M_1$	u	3.95 ± 0.42	4.60 ± 0.26	0.65 ± 0.49	1.2
	l	2.90 ± 0.30	3.94 ± 0.23	1.04 ± 0.38	1.4
Space-difference, $M_1 - M_1$	u	3.45 ± 0.37	3.76 ± 0.21	0.31 ± 0.43	1.1
	l	2.41 ± 0.25	2.99 ± 0.18	0.58 ± 0.31	1.2
Arch-space, $I_2 - I_2$	u	1.60 ± 0.17	2.63 ± 0.15	1.03 ± 0.23	1.6
	l	1.17 ± 0.12	1.31 ± 0.08	0.14 ± 0.14	1.1
Space-difference, $I_2 - I_2$	u	1.07 ± 0.11	2.03 ± 0.12	0.96 ± 0.16	1.9
	l	0.96 ± 0.10	1.03 ± 0.06	0.07 ± 0.12	1.1
Width of dent. arch at P_1	u	1.84 ± 0.21	2.60 ± 0.15	0.76 ± 0.26	1.4
» » » » » M_1	u	1.86 ± 0.20	3.10 ± 0.18	1.24 ± 0.27	1.7
Length of dent. arch	u	2.12 ± 0.23	2.25 ± 0.13	0.13 ± 0.26	1.1
Length in per cent of width	u	5.18 ± 0.55	6.30 ± 0.36	1.12 ± 0.66	1.2
Width of dent. arch at P_1	l	1.68 ± 0.18	2.00 ± 0.12	0.32 ± 0.22	1.2
» » » » » M_1	l	1.91 ± 0.20	2.50 ± 0.15	0.59 ± 0.25	1.3
Length of dent. arch	l	1.45 ± 0.23	2.05 ± 0.13	0.60 ± 0.26	1.4
Length in per cent of width	l	6.77 ± 0.71	8.80 ± 0.52	2.03 ± 0.88	1.3
Inclin. of medial incisors[1]	u	0.58 ± 0.03	0.74 ± 0.04	0.16 ± 0.05	1.3
Height of palatal vault	u	1.38 ± 0.15	2.27 ± 0.13	0.89 ± 0.20	1.6
Sag. relation betw. u. and l. jaw at M_1 (average)	—	1.92 ± 0.24	2.11 ± 0.13	0.19 ± 0.27	1.1
Sagittal overbite	—	2.03 ± 0.25	2.04 ± 0.13	0.01 ± 0.28	1.0
Vertical overbite	—	1.16 ± 0.15	1.63 ± 0.10	0.47 ± 0.18	1.4
Diff. in width betw. u. and l. jaw at P_1	—	1.80 ± 0.23	2.17 ± 0.14	0.37 ± 0.27	1.2
» M_1	—	1.72 ± 0.21	2.46 ± 0.15	0.74 ± 0.26	1.4

[1] 1 mm = 6.3°.

As to the characters in the tooth-position within the individual jaws, the quotient between the standard deviations in the population and in the fraternal twins (in cases without missing teeth) is on an average 1.3, and for the characters indicating the occlusion of the jaws, the mean value is 1.2 (table 24). The individual values vary between 1.9 (the space-difference of the upper incisors) and 1.0 (sagittal overbite). The standard deviation for the population is significantly higher than for the fraternal twins as to 5 characters (space and space-difference of the upper incisors, the width of the dental arch at M_1 in the upper jaw, the inclination of the upper incisors and the height of the palatal vault). Probable differences of the same type exist for 3 characters (the width of the dental arch at P_1 in the upper jaw, the difference in the arch-width between the jaws at M_1, and the vertical overbite). For the remaining 15 characters the differences in the standard deviations between the population and fraternal twins may be due to random variation, which fact naturally does not prevent that such differences might be proved on a larger material.

It is therefore obvious, that the actual dispersion in the population is greater than that which can be calculated on fraternal twins as regards the size of the teeth as well as certain characters of the toothposition. To which extent this circumstance depends on the fact that the heredity or the environmental factors vary more within the population than within the families will be discussed later.

CHAPTER VI.

LOSS OF TEETH IN TWINS, AND THEIR IMPORTANCE TO THE MATERIAL FROM A REPRESENTATIVE VIEWPOINT

When analysing the loss of teeth in identical and fraternal twins, the same method was used as given by *Dahlberg* (1926) when analysing the risk of death for twins at birth. The probability of loss of teeth in the individual has been obtained by placing all individuals with losses in relation to the total number of individuals, identical as well as fraternal twins. If this probability is expressed in per cent and termed p, then, of course, the probability that the individual may avoid loss of teeth becomes $(100 - p)$ per cent. By random distribution in twins, the probability of their both having loss of teeth then becomes $= p^2$ per cent. Similarly, the probability of their being both without loss of teeth becomes $= (100 - p)^2$ per cent; and the probability of one of them having losses, while the other non, becomes $= 2p\ (100 - p)$ per cent. The theoretical values calculated in this way have in table 25 been compared to the actual ones, and it appeared that the identical twins show a considerably smaller dissimilarity in per cent (i. e. one twin without, and the other with missing teeth) than presupposed by the theoretical values (the difference is 29.1±5.1 % in the upper jaw, and 33.8± 5.1 % in the lower). The fraternal twins also seem to show smaller dissimilarities than what is to be expected at random distribution (corresponding differences are 6.7± 5.0 % in the upper jaw, and 10.7±5.0 % in the lower). That smaller dissimilarities than expected are obtained,

Table 25. **Distribution of twin pairs without and with missing teeth (of one or both twins per pair) as compared with the theoretical distribution calculated on the assumption that loss of teeth are due to random causes. The frequency of twins with missing teeth is 32.3 per cent (29.5 per cent among identical twins and 35.0 per cent among fraternal twins) in the upper jaw and 36.5 per cent (37.9 per cent and 35.2 per cent respectively) in the lower jaw.**

Group	Twin pairs					
	without missing teeth		with missing teeth of one twin		of both twins	
	No.	Frequency %	No.	Frequency %	No.	Frequency %
Upper jaw						
Theoretical distribution ...		45.8		43.8		10.4
Identical twins	60	63.2	14	14.7	21	22.1
Fraternal twins	45	46.4	36	37.1	16	16.5
Diff. between observed and theoretical freq.:						
1. ident. twins		+ 17.4 ± 5.1		— 29.1 ± 5.1		+ 11.7 ± 3.1
2. frat. twins		+ 0.6 ± 5.1		— 6.7 ± 5.0		+ 6.1 ± 3.1
Lower jaw						
Theoretical distribution ...		40.3		46.4		13.3
Identical twins	53	55.8	12	12.6	30	31.6
Fraternal twins	46	46.9	35	35.7	17	17.4
Diff. between observed and theoretical freq.:						
1. ident. twins		+ 15.5 ± 5.0		— 33.8 ± 5.1		+ 18.3 ± 3.5
2. frat. twins		+ 6.6 ± 5.0		— 10.7 ± 5.0		+ 4.1 ± 3.4

should be conditioned by the similarity in environment, though, of course, it is also possible that the similarity is inherited because they have the same parents. Whatever the reason is for this, the still greater similarity in identical twins must, in any case, be an expression of the influence of heredity, since the difference between identical and fraternal twins is, that identical twins have the same genotype. These conclusions concern mainly the existence of caries because this is the main cause of the losses dis-

cussed here. The results agree with those previously obtained by *G. Dahlberg* and *B. Dahlberg* (1942).

From a representative viewpoint it is necessary to discuss the combination in that part of the material which could not be used for certain characters, because the teeth from where the measurements are taken were missing. This is particularly true of the width of the dental arch at M_1, the length of the dental arch, and the occlusion between the jaws at M_1 in the transversal and sagittal plane. For these characters a considerable part of the total number of twins could not be registered (between 17 % and 44 % for the identical, and between 38 % and 50 % for the fraternal pairs of twins). The reason why these characters evade examinations in such a great part of the material is because of the relatively high frequency in the loss of 6-years molars. So it can be questioned whether the origin of such losses is connected in any way with the concerned occlusal characters. Even if it is difficult to give any definite answer to this question, one should, however, be able to reckon with such losses being mainly dependent on caries, and having no connection with the tooth position; consequently, there is no reason to believe that the results should be incorrect because of the selection in question.

Even if M_1 is extracted because of caries, and not because of malocclusion, the extraction may cause a varying growth of the jaw. Therefore, cases with extraction of M_1 must of course be specially dealt with.

In cases with loss of P_1 there is more reason to suspect a certain selection of cases with small jaws, because such extractions are preferably carried out on orthodontic indications where crowding occurs. That part of the twin-material which is excluded due to extractions of P_1 is, it is true, essentially less than is found in losses of M_1, but still it is so large that the selection may be of importance. Thus, 10 % of the identical, as well as the fraternal twins are excluded for the width of the dental arch at P_1; and for the differences in the width of the dental arch between the

jaws, 15 % of the identical and 18 % of the fraternal twins are also excluded. It is therefore necessary to read the result as regards these characters with some caution, as they probably do not express, the whole variation within the population.

CHAPTER VII.

THE VARIATION IN TWINS REGARDING BREADTH OF TEETH AND OCCLUSION

In the preceeding chapters perhaps a too detailed account of the material has been given, and especially as to its representativeness and of the method of investigation employed. Furthermore, an analysis has been made of the variation found in fraternal twins as compared to that of the population. By means of this it was proved that the variation of the tooth-breadth, as well as of the majority of occlusal characters is somewhat greater within the population than found in pairs of twins, for whom the genetic differences are limited by the fact that they possess the same parents; and the environmental differences because they are brought up in practically similar environments.

In the following, the influence of non-genetic and genetic factors on the occlusion will be examined by comparing the dissimilarities within the identical and fraternal pairs of twins. Also the variation, measured by means of the dispersion of dissimilarities between the left and the right side, will for some characters be compared with the corresponding variation in identical pairs of twins.

It has long been known that identical twins have the same genotype, and the difference between them is, therefore, an expression of the environmental effect in the term's widest meaning. In addition, there exist for fraternal pairs of twins differences conditioned by heredity. In the chapter on the statistical method, an explanation of the method was given which will be used here for the analysis of the twin-material to determine the relative effect of heredity and environment. However, there is a question that re-

quires a somewhat more detailed discussion. Professor *Dahlberg* has been kind enough to show me a non-published paper with certain viewpoints important to research work on twins, and I should like to express my gratitude to him for his kindness. This work emphasizes that differences between pairs of twins may occur through a variation of the internal environment. By internal environment is meant the type of cells in which the genes are effective. It is conceivable that, for instance, a slight difference in pH, a difference in temperature due to the intensity of the metabolism between the right and the left side, causes certain dissimilarities which cannot directly be attributed to environment, but which are neither conditioned by heredity. Therefore Dahlberg has suggested a division into three groups of etiological factors, namely, genetical, environmental and internal factors showing random distribution between left and right side, and also between co-twins on their left and right side respectively. Dahlberg points out that these internal factors are particularly of importance concerning those characters conditioned by genes with a low penetrability.

Mesio-distal size of the teeth. Concerning the occurrence of malocclusions, one must take into consideration that both the tooth-breadth, and the size of the jaws are of importance. The tooth-breadths have naturally a more or less decisive influence especially on crowding and spacing. Therefore the tooth-breadth will mainly be discussed from this viewpoint. It should, however, be pointed out that the twin-material examined is taken from the normal population, and therefore, any appreciable occurrence of more extreme malocclusions cannot be expected. With respect to this, an account of the most pronounced malocclusions is given in a special chapter, and are discussed individually.

Firstly an examination has been made as to the difference of the tooth-breadth which may be found in an *individual*. The size of the systematic and accidental deviations between the right and left side was determined

for the teeth I_1, I_2 and C in the upper jaw. The reason why only three teeth were examined is that it would require too much work to make calculations on all teeth. The teeth in question have been selected because the front-teeth are the teeth which have shown most frequently unimpaired tooth-breadths on both side. The upper teeth are preferable to those of the lower jaw because they are larger, and the magnitude of the deviations becomes, therefore, greater here than in the lower jaw. It is also of particular interest to examine I_2 in the upper jaw which is known for its great variation from a morphological viewpoint.

These calculations have been made partly for the twins (one twin of each pair), and also partly for an average-material consisting of 227 children at the age of 13 (140 boys and 87 girls). Cf. table 26.

Table 26. **Mean difference and standard error of the mean difference, $M_D \pm \varepsilon (M_D)$, and the standard deviation of the differences, σ_D, between left and right side in the tooth-breadth (mesio-distal width in mm) of I_1, I_2 and C in the upper jaw.**

Type of twins	Sex	I_1			I_2			C		
		No. of tooth pairs	$M_D \pm \varepsilon (M_D)$	σ_D	No. of tooth pairs	$M_D \pm \varepsilon (M_D)$	σ_D	No. of tooth pairs	$M_D \pm \varepsilon (M_D)$	σ_D
Identical	M	37	0.07 ± 0.037	0.22	38	0.15 ± 0.058	0.36	33	0.00 ± 0.038	0.22
	F	54	0.05 ± 0.023	0.17	50	0.12 ± 0.054	0.38	48	0 ± 0.024	0.16
Fraternal	M	42	0.13 ± 0.028	0.18	42	0.10 ± 0.042	0.27	33	0.00 ± 0.031	0.18
	F	52	0.08 ± 0.030	0.22	48	0.06 ± 0.050	0.34	47	0.07 ± 0.029	0.20
Average mat. 13 years	M	114	0.04 ± 0.021	0.22	113	0.09 ± 0.023	0.25	112	0.03 ± 0.016	0.17
	F	55	0.04 ± 0.024	0.18	52	0.05 ± 0.038	0.27	59	0.03 ± 0.018	0.14
Total		354	0.06 ± 0.010	0.19	343	0.09 ± 0.016	0.30	332	0.02 ± 0.009	0.17

All the differences are positive.

For I_1 and I_2 respectively, the mean value of the differences between the tooth-breadth values of the left and the right side deviate significantly from 0. For the sum of

the twin-material and the average-material this mean value is for $I_1 = +0.06 \pm 0.01$ mm., and for $I_2 = +0.09 \pm 0.02$ mm. For C the mean value of the differences is also positive ($= +0.02 \pm 0.01$ mm.), but for this tooth the deviation from 0 may be due to chance. One explanation of these differences between the left and the right side is that the measuring instrument was held differently for the right and the left side. A slight inclination of the instrument causing too high values when used on the left-hand side might occur, because this side is more inconvenient to measure than the right-hand side. Such an error of measurement should have greater effect for the incisors than for canines, the latter being more rounded in shape than the former. Naturally, it is also conceivable that the found differences are real.

In order to determine the size of the left-right variation of the tooth-breadth, the standard deviation for the differences between the left and the right side were calculated (see table 30). For I_1 this is 0.19 ± 0.007 mm.; for $I_2 =$

Table 27. **The frequency of discrepancies of the tooth-breadth (in per cent of total nummer of tooth-pairs) between left and right side of 0.25—0.50 mm and of 0.50 mm or more for I_1, I_2 and C in the upper jaw (according to Ballard, 1944).**

Tooth	No. of teeth measured	Discrepancy of 0.25—0.50 mm	Discrepancy of 0.50 mm or more
I_1	999	2.8	9.5
I_2	972	4.0	14.3
C	868	3.4	9.1

0.30 ± 0.012 mm., and for $C = 0.17 \pm 0.007$ mm. according to the calculations on the sum of the twin and average-material. The random differences between the left and the right side are then considerably greater than the systematic deviations which are obviously of minor importance in this connection. It also appears that I_2 shows greater variation as to the tooth-breadth values than I_1

and *C*. As regards to the sequence of the tooth disparity, the result agrees with *Ballard*'s (1944) examination of 500 malocclusion-cases as to the differences between the right and the left side of the teeth from I_1 to M_1. Ballard obtained the following differences between the left and the right side for the teeth I_1, I_2 and *C* (table 27).

Table 28. **The frequency of discrepancies (in per cent of total number of tooth-pairs) of the tooth-breadth between left and right side of 0.5 mm or more and of 1.0 mm or more for I_1, I_2 and *C* in the upper jaw.**

Tooth		Total No. of tooth-pairs		Frequencies in per cent of total number of tooth-pairs			
				Discrepancy of 0.5 mm or more		Discrepancy of 1.0 mm or more	
		Ident. twins	Frat. twins	Ident. twins	Frat. twins	Ident. twins	Frat. twins
I_1	First twin	91	94	0.0	4.3	0.0	0.0
	Second twin	87	90	3.5	3.3	0.0	0.0
I_2	First twin	88	90	18.2	15.6	2.3	1.1
	Second twin	77	83	19.4	9.6	2.6	0.0
C	First twin	81	80	2.5	3.7	0.0	0.0
	Second twin	71	72	2.8	1.4	0.0	0.0

For the sake of comparison, and for the determination of the frequency of the larger dissimilarities, similar calculations were made for the twins as to the discrepancies: 0.5 mm. or more, 1.0 mm. or more, respectively (table 28). The frequency of dissimilarities of 0.5 mm. or more, between the left and the right side is significantly less in the author's material than in Ballard's material as regards I_1 and *C* (diff. $= 6.7 \pm 1.6$ per cent and 6.5 ± 1.7 per cent respectively), whereas they show approximately the same figures for I_2 (diff. $= 1.4 \pm 2.5$ per cent). It is possible that these differences are caused by the different combination of material (average-material and malocclusion, respectively), but it might also be due to different methods used

Table 29. **Standard deviation, σ_m, in mm of the differences between double determinations for I_1, I_2 and C on left and right side in the upper jaw.**

σ_m is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the difference between the first and second measurement of the same tooth and n the number of twin pairs.

Tooth	Left side		Right side	
	n	$\sigma_m \pm \varepsilon(\sigma_m)$	n	$\sigma_m \pm \varepsilon(\sigma_m)$
I_1	40	0.08 ± 0.010	40	0.07 ± 0.008
I_2	39	0.12 ± 0.013	39	0.10 ± 0.011
C	38	0.08 ± 0.009	36	0.06 ± 0.007

for measuring. As Ballard did not give any specifications as to the size of his errors of measurement the cause cannot, however, be determined.

According to *Korkhaus'* figures for I_2 in the upper jaw (see page 39), the dissimilarities between the left and the right side seem to be less in identical than in fraternal twins. Thus, the mean deviation in per cent of the mean value was calculated as being 0.64 ± 0.06 per cent for the former, and 2.46 ± 0.30 per cent for the latter. In the author's material no such tendency exists, the corresponding figures being 4.4 ± 0.50 per cent for male, and 9.6 ± 0.46 per cent for female identicals twins, and 3.2 ± 0.35 per cent for male and 4.1 ± 0.42 per cent for female fraternal twins.

When explaining the greater left-right variability of I_2 as compared to I_1 and C, the following possibilities are especially conceivable:

1. The errors of measurement are greater for I_2 than for the other teeth.

2. The difference depends upon internal factors with random distribution either so that such factors vary more at I_2 than at I_1 and C, or that the genetic factors are more sensitive to such variations in the case of I_2 than they are for the other teeth.

3. Genotypic asymmetries of constitutional nature are more common for I_2 than for the other teeth.

The contribution of the errors of measurement to the standard deviation for the differences between the left and the right side, can be determined by calculating the standard deviation of the differences between the double determinations (see page 64). These standard deviations were calculated for the right and the left side (table 29).

Table 30. **Standard deviation, σ, in mm of the differences between left and right side for I_1, I_2 and C in the upper jaw, without and with correction in regard to the standard deviation in table 29, σ_m, calculated on twins (one twin in each pair) and an average material (13-year of age).**

σ_D is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n} - b^2}$, where d is the difference between left and right side, b the mean of the differences and n the number of tooth-pairs.

σ_c is calculated according to the formula $\sqrt{\sigma^2 - \sigma^2_m}$.

Tooth	No. of tooth-pairs	Standard deviation of the differences between left and right side	
		Without correction $\sigma_D \pm \varepsilon(\sigma_D)$	With correction $\sigma_c \pm \varepsilon(\sigma_c)$
I_1	354	0.19 ± 0.007	0.17 ± 0.006
I_2	343	0.30 ± 0.012	0.28 ± 0.011
C	332	0.17 ± 0.007	0.15 ± 0.005

These figures are all significantly less than the corresponding standard deviations for the differences between the left and the right side, which shows that these cannot only be explained as being dependant on such methodical errors. These errors are possibly somewhat greater for I_2 than for I_1 and C (the differences between those of the double determinations are for I_2—I_1 = 0.032 ± 0.016 mm. on the left side and 0.028 ± 0.014 mm. on the right side and for I_2—C = 0.040 ± 0.016 mm. and 0.037 ± 0.013 mm. respectively).

It is therefore conceivable, that the higher values of

dispersion for I_2 as compared with I_1 and C as to the differences between the left and the right side are, to some extent, dependant on the varying sizes of the errors of measurement for the mentioned teeth. In order to decide to which extent this is the case, a calculation has been made of the standard deviation, which is independent of the errors of measurement, for the differences between the right and the left side. Table 30 shows the standard

Table 31. **Standard deviation, σ, in mm of the differences between left and right side for I_1, I_2 and C in the upper jaw according to cases without crowding and cases with a deficit of space of 0.5 mm or more on at lest one side of the jaw, at certain sections of the arch (cf. fig. p. 54).**

σ is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n} - b^2}$, where d is the difference between left and right side, b the mean of the differences and n the number of tooth-pairs.

Tooth	Arch-section	No. of tooth-pairs		Standard deviation of the differences between left and right side	
		Cases without crowding	Cases with crowding	Cases without crowding	Cases with crowding
I_1	S_3 and S_4	85	50	0.19 ± 0.014	0.21 ± 0.021
I_2	S_3 and S_4	85	36	0.26 ± 0.020	0.23 ± 0.028
C	S_2 and S_5	79	43	0.14 ± 0.011	0.17 ± 0.017

deviation in question with, and without, such elimination of the error of measurement. These calculations indicate that the errors of measurement are of minor importance as the cause of the observed differences between the left and the right side.

One question, however, which must be discussed in connection with this, is whether it is possible to determine completely the errors of measurement through double determinations of the tooth-breadth. It is conceivable that, especially in the case of crowding, a correct measurement of the tooth-breadth is not possible. A double determina-

tion gives eventually no information about such errors of measurement, as for both measurements an incorrect placing of the instrument may be inevitable. In order to determine the influence of this source of error, a calculation of the standard deviation has been made for I_1, I_2 and C as to the differences between the left and the right side, partly in cases without crowding or with spacing in the sections of the dental arch concerned, and partly in cases with a lack of space of at least 0.5 mm. either on one side or on both. In the cases of I_1 and I_2 the space-figures in the sections S_3 and S_4 have been used, while the space-conditions for C appear from the sections S_2 and S_5 (see page 54). Table 31 shows the standard deviation calculated on the average-material of children at 13 years of age. As the groups correspond well with eachother, it is obvious that this source of error is of minor importance. Therefore, it can be considered as proved that the differences shown between the left and the right side are, on the whole, real.

Whether the greater left-right variation of I_2 as compared to I_1 and C depends upon random variation between the left and the rigt side during the development of the different teeth, or upon the occurrence of genotypical asymmetries, is scarcely possible to judge at present. The possibilities of random dissimilarities between the left and the right side should naturally be greater for teeth which are situated further from the middle line than for those laying nearer, and this might then be the cause of the difference between I_1 and I_2. The reason why C does not vary to an even larger degree, but on the contrary, varies less than I_2 might be that this tooth is situated nearer the large blood vessels, which should give a more stable distribution than those in the periphery. On the whole, the internal environment varies more for identical twins than for fraternal twins which is due to anastomising. Furthermore, one must consider that the environment *in utero* varies more for twins than for the average population due

to dissimilarities in nutrition. These circumstances should be able to explain the fact that the standard deviation for the differencens between the left and the right side is possibly greater as to I_2 for identical twins than for the population (the difference $= 0.11 \pm 0.044$ mm. for males, and 0.11 ± 0.046 for females). It is, however, probable that these environmental differences are of minor importance where the permanent teeth are concerned, and that the found differences are therefore due to random variation.

The particularly great differences of the tooth-breadth for I_2 in the upper jaw is probably connected with the already long known morphological variability in this tooth. It varies from a typical incisor with a well formed edge to an almost rudimentary conical pegtooth. This tooth is also relatively often congenitally missing (*Dolder* 1936), and many family-descriptions have been published indicating that this is a hereditary phenomenon (e. g. *Mc Quillen* 1870, *Magitot* 1887, *Sergi* 1914, *Borchardt* 1922, *Wallton* 1925, *Thomas* 1926, *Steiner* 1927, see also *Korkhaus* 1939). These circumstances have, indeed, been interpreted by different authors as being a sign of the disappearance of the lateral incisors in the jaws of the human being. Therefore, the great variability and the relatively great differences between the left and the right side can be explained as a sign that heredity has a relatively low penetrability regarding this tooth, whereby even the rather small variations in the internal environment of the teeth might cause great alterations in the shaping of the tooth, and in extreme cases completely prevent its occurrence.

Whether the occurrence of genotypical asymmetries should be considered where the tooth-breadth is concerned, and especially in I_2, is not possible to decide without special investigations. However, it should be considered improbable that the great asymmetries occurring in I_2 are caused only by random dissimilarities of the internal environment of the teeth, and it is, therefore, possible that genotypical asymmetries have a certain influence.

Concerning the differences of the tooth-breadth *in twins* certain causative factors must be considered in addition to those which might cause asymmetries. Thus, the question as to the effect of the external environment arises for identical as well as fraternal twins. Firstly, one ought to mention the general nutritive conditions *in utero* as well as during the first years after birth until the tooth-breadth is determined by the calcification of the enamel. Furthermore, the twins might more accidentally be exposed to such dissimilarities in environment, as for example re-

Table 32. **Standard deviation, σ_D, of differences in tooth-breadth (mesio-distal width in mm) between left and right side and standard deviation, σ_0, of intrageminal differences in tooth-breadth in identical twins for I_1, I_2 and C in the upper jaw.**

σ_D is calculated according to the formula $\sqrt{\frac{\Sigma a^2}{n} - b^2}$, where a is the differences between left and right side and b the mean of the differences.

σ_0 is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the difference between the co-twins and n the number of twin pairs.

Tooth	Differences in tooth-size between left and right side		identical twins			
	No. of twins	$\sigma_D \pm \varepsilon(\sigma_D)$	No. of pairs	Left side $\sigma_0 \pm \varepsilon(\sigma_0)$	No. of pairs	Right side $\sigma_0 \pm \varepsilon(\sigma_0)$
I_1	91	0.19 ± 0.014	89	0.23 ± 0.018	89	0.20 ± 0.015
I_2	88	0.37 ± 0.028	84	0.39 ± 0.030	82	0.37 ± 0.029
C	81	0.18 ± 0.014	77	0.21 ± 0.017	78	0.20 ± 0.016

garding illnesses, that the tooth-size might be influenced. A conception of the effect of external environment should be obtained by a comparison between the standard deviations of the differences between the left and the right side and between identical twins respectively (table 32).

Quite unexpectedly, the dispersion of the differences between left and right side seem to be almost the same

Table 33. **Standard deviation, σ_0, of intrageminal differences in tooth-breadth (mesio-distal width in mm) of different teeth for identical and fraternal twin pairs.**

σ_0 is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the intrageminal difference and n the number of twin pairs.

Tooth	No. of twin pairs		Identical twin pairs	Fraternal twin pairs
	Id.	Fr.	$\sigma_0 \pm \varepsilon(\sigma_0)$	$\sigma_0 \pm \varepsilon(\sigma_0)$
			Upper jaw	
I_1	91	93	0.19 ± 0.014	0.52 ± 0.038
I_2	90	98	0.30 ± 0.022	0.58 ± 0.041
C	87	87	0.17 ± 0.013	0.39 ± 0.030
P_1	62	73	0.17 ± 0.015	0.43 ± 0.035
P_2	53	60	0.22 ± 0.021	0.43 ± 0.039
M_1	45	45	0.30 ± 0.031	0.53 ± 0.055
$I_1 + I_2 + C$	63	70	0.94 ± 0.084	2.33 ± 0.20
$I_1 + I_2 + .. + M_1$	23	22	1.28 ± 0.19	4.69 ± 0.71
			Lower jaw	
I_1	93	91	0.14 ± 0.010	0.32 ± 0.024
I_2	95	94	0.15 ± 0.011	0.40 ± 0.029
C	93	95	0.16 ± 0.011	0.34 ± 0.024
P_1	80	95	0.18 ± 0.014	0.40 ± 0.031
P_2	62	67	0.26 ± 0.023	0.45 ± 0.038
M_1	43	47	0.34 ± 0.036	0.64 ± 0.066
$I_1 + I_2 + C$	77	77	0.52 ± 0.042	1.70 ± 0.14
$I_1 + I_2 + .. + M_1$	30	31	1.11 ± 0.14	4.17 ± 0.53

size as the dispersion of the differences between identical pairs of twins. However, the latter dispersion seems to be somewhat greater though the difference is not significant. (The differences in the standard deviation in relation to the left side of the fraternal twins, where the differences are most evident, are for $I_1 = +0.04 \pm 0.023$ mm., for $I_2 = +0.02 \pm 0.041$ mm., and for $C = +0.03 \pm 0.022$ mm.) Even if there is such a difference it is obviously insignificant which fact indicates that the factors governing the variation in identical pairs of twins are of a similar kind as

those causing differences between the halves of the body i. e. the factors which at an early stage become effective, probably in the embryonic stage only, while on the other hand, the later differences in environment must be of minor importance.

In the case of fraternal pairs of twins, as compared to the conditions in identical pairs, the difference in genetic factors is added as a differentiating factor. Because of this, also the dispersion of the intrageminal differences in the tooth-breadth for all examined teeth become clearly greater in the fraternal than in the identical pairs of twins (table 33). It can be asked in connection with this: in which way does the difference in genetic factors affect the tooth-size? Here it is probable that one is partly dealing with a general variation of the size of the body as a whole, causing consequently that big individuals also have larger teeth than small ones. It is, however, possible that we also have genetic factors with a more local effect, either on the whole system of teeth, or on groups of teeth and finally on the individual tooth. This question will be discussed later.

As regards the tooth-position, the variations described above are naturally of minor interest. It is conceivable that these variations are more or less smoothed out where the whole dental arch is concerned. This is why a calculation has also been made over which differences exist within pairs of twins for certain sums of tooth-breadths, namely, the sum of the six front teeth and the sum of all the teeth from the first molar on the right side to the same tooth on the left side (table 33). It appears from this that the differences occurring between identical pairs of twins are not insignificant. If one reckons with 3 times the standard deviation, there occurs for the sum of the tooth-breadths from M_1—M_1 differences from 0 to appr. 4 mm. in the upper jaw, and from 0 to appr. 3 mm. in the lower jaw. In fraternal pairs of twins, the dispersion of the intrageminal differences in the whole sum of tooth-breadths is consider-

ably greater than in the identical. This is due to the effect og genetic dissimilarities. Thus, differences from 0 to appr. 14 mm. occur in the upper jaw, and from 0 to appr. 12—13 mm. in the lower jaw. These differences are to only a slight degree caused by errors of measurement.[1]

Space of the teeth for the whole dental arch. Malocclusions in general are mainly of two types. Thus, they can partly be ascribed to the relative space so that the teeth have too little or too much space i. e. show crowding or spacing, and partly to the general structure of the jaws so that they do not correspond with eachother, causing anomalies in the occlusion of the jaws to arise. We will first concentrate our attention on the deviations in the space, and mainly discuss here the absolute space within the jaws. It must then be emphasized that what should be determined here, is preferably the actual size of the jaws i. e. the space which the teeth can utilize. However, it is impossible to measure this space because fixed and easily determinable points on the jaw base are missing. The inclination of the teeths is of some importance in this connection. If the teeth are inclined outwards, they will naturally be able to utilize better the space in the jaws than if they are inclined inwards. One should preferably measure the apical base as well as the space which exists at the crowns of the teeth (the apical base is a term introduced by *Axel F. Lundström,* 1923, by which is meant the space about the roots of the teeth). The former is, however, impossible to measure. Therefore, in order to determine the space of the jaws hardly any other method remains than to measure it using the crowns of the teeth as starting points, e. g. in the same way as was used in this examination from M_1—M_1. The space which is determined in this way is, however,

[1] The standard deviation of the differences between two measurements on the same individual of the sum of tooth-breadths from M_1—M_1 is 0.57 mm. in the upper jaw and 0.68 mm. in the lower jaw, calculated according to 23 and 24 double measurements respectively.

not only conditioned by the size of the jaw, but also by the size and number of the teeth, and of course, also by their position. For example, if the wisdom teeth are very small or missing, the space which the other teeth can dispose of, for the rest under the same conditions, becomes naturally larger than if these teeth are large. In other words, the space must to some extent be correlated to the number and size of the teeth.

We will firstly compare the differences between the left and right side of an individual. Those differences that occur here depend upon internal and environmental factors, and also genotypical asymmetries as was stressed when discussing the tooth-breadths. The question is then how to determine the median line. Firstly it can be conceived as starting from a line of sight drawn from other points of the face laying on the median line of the head (the highest point on the bridge of the nose etc.). Such a method is firstly most inaccurate, and secondly hardly correct from a theoretical viewpoint. The center required is the anatomical center which is characterized by the coalescence-line of the various primordia of the jaws. In the upper jaw a conception as regards this can be obtained by building on raphe palatina, and in the lower jaw from the location of the ligament of the tongue, or from spina mentalis, which can be determined by means of X-ray. As a rule, the space between the medial incisors should coincide with the line of sight of these formations. As to the upper jaw it was possible to examine this in practically all cases in the twin-material. It was impossible in 7 cases because the palatal vault was imperfectly reproduced on the models. In some few cases noticeable dislocations were found, namely in 6 individuals out of which 3 belonged to different identical, and 3 to different fraternal pairs of twins. The dislocations are however moderate in size and are at their highest 2—3 mm. Usually the inclination concerns only the crowns of the front teeth while the points of the roots lie normally. In 4 of these 6

cases the inclination is associated with a general lack of space which is most strongly expressed at the canine on that side towards which the midline is displaced. It also seems probable that dislocations occur partly as a result of the eruption of the teeth whereby accidental deviations in the period of eruption may determine the side which will win the struggle for space. In one of the remaining cases where the midline was inclined to one side, the canine was impacted on the same side and seemed to be dislocated in a lingual direction judging from a clear convex curvature in the palate lingually about the lateral incisor. In the last case no particular deviations were found in the dental arch which could be associated with the displacement of the midline.

The examination shows that displacement of the space between the medial incisors is partly rare and partly of inconsiderable size. It seems, therefore, justifiable to base the comparison between the halves of the body on this point, which also in comparison to the midline of the palate has the advantage of being easier to determine accurately. It can be discussed whether those cases in which the midline could not be compared with raphe palatina, or which showed displacements of the midline, should be omitted when calculating. Due to the fact that these individuals are very few in number and the displacements are inconsiderable it should have no practical significance whether they are omitted or not. It seems, however, more consequent to use the same method of calculation for the upper jaw as for the lower jaw where a corresponding omission is impossible. The following calculations have therefore been made without such a selection.

Any systematic differences between the space-values of the left and right side (measured on each side as the sum of 3 sections from I_1—M_1, see page 54) could not be proved in the upper jaw, but, on the other hand, could be proved in the lower jaw, where the mean value of the differences in the space between the left and right side was significant

among the older pairs of twins ($+0.64 \pm 0.15$ mm.). It is naturally conceivable that a true difference exists between the halves of the body, but it might also be that the difference is caused by a systematic error of measurement. This may arise in cases of crowding at the medial incisors. If these teeth are located so that their mesial points of contact are displaced in relation to eachother it can be doubted which point should be utilized as the center.

The dispersion of the differences between the arch-space on the left and on the right side has been determined, as for the tooth-breadths, by the standard deviation of these differences in the identical and fraternal twin-material (table 34) in which, however, only one twin was employed in order to avoid the correlation which otherwise should have been necessary to reckon with due to the mutual similarity of the co-twins. Besides, it must be pointed out that if only identical twins are employed (in which case the material becomes smaller) the figures show no significant difference compared to those which are obtained from the conjoined material. According to these calculations the differences amount to a maximum of 3 to 4 mm. (= 3 times the standard deviation) in the upper as well as in the lower jaw. The dispersion-figures in the younger age group (12—15 years) agree well with those in the older one, (16—40 years) which is why no noteworthy change in those differences existing between the halves of the body after the age of 12—15 years seems to take place.

The difference between the left and right side is of course to some extent caused by errors of measurement. A special calculation made of those differences between the halves of the jaws which are caused in this way show, however, that the influence of errors of measurement is small (table 34).

From what has been shown above, it is unnecessary to reckon with noteworthy deviations of the space between the both I_1 in relation to the anatomical midline, then the

Table 34. **Comparison between variability between left and right side and variation in identical twins in regard to the sum of tooth-breadths from I_1 to M_1 and to the space in the dental arches from I_1 to M_1 (in mm). The variation is expressed in the standard deviation, σ, for the differences.**

σ_m of differences between double measurements on the same individual and σ_0 of intrageminal differences are calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the difference and n the number of pairs investigated.

σ_D is used when the mean of the differences show a significant deviation from 0. The formula then used is $\sqrt{\frac{\Sigma d^2}{n} - b^2}$, where b is the mean of the differences.

Character	Type of variability	Type of twins	Differences[1] between	Age, years	Upper jaw		Lower jaw	
					No.	$\sigma \pm \varepsilon(\sigma)$	No.	$\sigma \pm \varepsilon(\sigma)$
Tooth-breadth	σ_m		l — l	12—40	26	0.31 ± 0.04	29	0.39 ± 0.05
	σ_m		r — r	12—40	26	0.24 ± 0.03	29	0.42 ± 0.05
Arch-space ...	σ_m		l — l	12—40	40	0.31 ± 0.03	40	0.33 ± 0.04
	σ_m		r — r	12—40	40	0.42 ± 0.05	40	0.42 ± 0.05
Tooth-breadth	σ_D	Id+Fr	l — r	12—40	49	0.52 ± 0.05	63	0.57 ± 0.05
Arch-space ...	σ_D	Id+Fr	l — r	12—15	88	1.19 ± 0.09	86	1.16 ± 0.09
	σ_D	Id+Fr	l — r	16—40	57	1.22 ± 0.11	51	1.05 ± 0.10
	σ_D	Id+Fr	l — r	12—40	145	1.20 ± 0.07	137	1.15 ± 0.07
Tooth-breadth	σ_0	Id	l — l	12—40	10	(0.73)	7	(0.82)
	σ_0	Id	r — r	12—40	10	(0.72)	7	(0.49)
Arch-space ...	σ_0	Id	l — l	12—15	28	2.11 ± 0.28	25	1.12 ± 0.16
	σ_0	Id	l — l	16—40	29	1.41 ± 0.18	23	0.88 ± 0.13
	σ_0	Id	l — l	12—40	57	1.75 ± 0.16	48	1.00 ± 0.10
	σ_0	Id	r — r	12—15	28	1.74 ± 0.23	25	1.28 ± 0.18
	σ_0	Id	r — r	16—40	29	1.33 ± 0.17	23	0.68 ± 0.10
	σ_0	Id	r — r	12—40	57	1.52 ± 0.14	48	1.03 ± 0.10

[1] l = left side of the jaw from I_1 to M_1.
r = right side of the jaw from I_1 to M_1.

differences must firstly be conditioned by the different location of the posterior point of measurement, i. e. M_1. Such dissimilarities might depend upon random factors

during the development in agreement with the tooth-breadths. That such factors are of importance is self-evident since the measurements in question are chiefly conditioned by the tooth-breadths. The dispersion of the tooth-size which exists as to the differences between the halves of the jaws (the sum of the individual tooth-breadths from I_1—M_1) is, however, considerably less than that which characterizes the corresponding difference in the space (the difference = 0.68 ± 0.09 mm. in the upper jaw and 0.58 ± 0.09 mm. in the lower jaw, see table 34). These random factors can, therefore, only in part explain the dissimilarities between the halves of the jaw in the space. Besides, it is uncertain to which extent the deviations of the tooth-size between the halves of the jaws express themselves in corresponding deviations in the space. It is also conceivable that the result of the dissimilarities in the tooth-size is increased crowding (or decreased spacing) in the side where the larger teeth are situated as compared with that side where the smaller ones are situated.

It is naturally possible that random factors similar to those which determine the tooth-size also influence the development of the jaws, but it is impossible to settle this question. Apart from random factors, the differences might be conditioned by environmental factors of which premature loss of deciduous teeth must be considered; this could naturally occur only in one half of the jaw, or in both halves, but with considerable intervals of time. Another environmental factor is a difference in the functioning of the right or left side of the jaws. It is conceivable that the differences are conditioned by the fact that one for some reason or other chews mainly on one side, and that not only the function causes a different development but that the pressure of the muscles also affect the shape of the dental arch. Finally genetic differences in some cases may occur through genotypical asymmetries, but there is no particular reason to expect this. It must, however, be pointed out that to what extent M_3 develops

in only one half of the jaw due to genetic or non-genetic factors, this must be of some importance (cf. *Selmer-Olsen*, 1937). Agenesia of the other teeth is of no importance in this material, because the accounted differences refer to individuals without missing teeth apart from M_3. Because an X-ray examination was not made, the existence of this tooth in the jaw could not be determined.

Similarly to the tooth-breaths, we are to compare dissimilarities as to the space between left and right side in the individuals with the dissimilarities within identical pairs (between the left resp. right half of the jaw of the twin-pairs). It is natural here, of course, that the intrageminal variation is greater than the one between left and right side, as in the former case the influence of environment is increased by such environmental factors which cause differentiation in the development of the twins on the whole. That this is the case can also be proved, at least as far as the upper jaw is concerned, where the intrageminal variation on the left side is significant and on the right side possibly greater than the left-right variation (diff. in the standard deviations $= +0.55 \pm 0.17$ mm. and $+0.32 \pm 0.16$ mm. respectively). The effect seems less pronounced in the older than in the younger age-group associated with a decrease, though not significant, of the intrageminal variation with age. In the older pairs the difference in both standard deviations may very well be due to random variation.

The figures for the lower jaw give no proof that the intrageminal variation is greater than the asymmetric. In the younger pairs there exists, however, a tendency in this direction on both left and right side, and it is therefore conceivable that on a larger material significant differences could be proved. In the older pairs there seems to be, if any, a somewhat smaller intrageminal variation than an asymmetric (the difference in the standard deviation $= -0.17 \pm 0.16$ mm. on the left side and -0.37 ± 0.14 mm. on the right side). The differences are however not signi-

ficant and it is quite possible that they are due to random variation. It is, nevertheless, not impossible that such a difference might exist. This should be able to arise in genotypical asymmetries with a tendency to occur on the same side in twins.

The investigation shows that in identical pairs of twins the difference between intrageminal and left-right variation is rather small, this indicates that, on the whole, the same factors cause dissimilarities between identical twins and between the halves of the body. It must be pointed out that age does not seem to have any decisive influence, but that the material is rather too small to allow a closer analysis of the age factor.

The influence of genetic factors is determined by comparing the variation in the fraternal pairs with that found in the identical pairs. In this comparison, the sum of the space values of the left and right side were used. It is necessary here, to take into consideration the influence of age on the size of the intrageminal differences, since the age distribution in pairs without missing teeth is essentially different in identical as compared to those found in the fraternal twins. The proportion between the number of younger and older is then 1.2:1 in the identical, and 3.9:1 in the fraternal. It must be emphasized that a decrease with age of these intrageminal differences is probable from a theoretical viewpoint. Concerning the height of the body *Dahlberg* (1931) has shown that environmental factors of intermittent type might cause differences during the period of growth which, later on, are smoothed out.

It has already been pointed out that the intrageminal differences for the halves of the jaws seem to decrease with age, and it should naturally be possible to prove this tendency as regards the whole jaw. This also seems to be the case, at least as far as the lower jaw is concerned where the difference in the standard deviation of the differences is almost significant ($= 1.05 \pm 0.37$ mm.). In the upper

Table 35. **Standard deviation, σ_0, in mm of intrageminal differences of the space and of the space-difference in the dental arch. Twin pairs without missing teeth in different age-groups in the upper and lower jaw.**

σ_0 is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the intrageminal difference and n the number of twin pairs.

Character	Jaw	Age, years	No. of pairs		Ident. twin pairs	Frat. twin pairs
			Id	Fr	$\sigma_0 \pm \varepsilon(\sigma_0)$	$\sigma_0 \pm \varepsilon(\sigma_0)$
Arch-space $M_1—M_1$ ..... (in mm)	u	12—15	30	34	3.08 ± 0.40	5.58 ± 0.68
	u	16—40	30	10	2.25 ± 0.29	(5.62)
	u	12—40	60	44	2.65 ± 0.24	5.59 ± 0.60
	l	12—15	27	38	2.33 ± 0.32	4.22 ± 0.48
	l	16—40	25	8	1.28 ± 0.18	(3.45)
	l	12—40	52	46	1.87 ± 0.18	4.09 ± 0.43
Space-difference $M_1—M_1$ (in mm)	u	12—15	29	34	2.94 ± 0.39	5.16 ± 0.63
	u	16—40	30	10	2.12 ± 0.27	(3.82)
	u	12—40	59	44	2.51 ± 0.23	4.88 ± 0.52
	l	12—15	26	37	2.47 ± 0.34	3.65 ± 0.41
	l	16—40	25	8	1.75 ± 0.25	(1.98)
	l	12—40	51	45	2.11 ± 0.21	3.40 ± 0.36
Arch-space $I_2—I_2$..... (in mm)	u	12—15	30	34	0.91 ± 0.12	2.32 ± 0.28
	u	16—40	30	10	1.49 ± 0.19	(2.09)
	u	12—40	60	44	1.22 ± 0.11	2.27 ± 0.24
	l	12—15	28	38	1.17 ± 0.16	1.73 ± 0.20
	l	16—40	25	8	0.68 ± 0.10	(1.30)
	l	12—40	53	46	0.95 ± 0.09	1.66 ± 0.17
Space-difference $I_2—I_2$... (in mm)	u	12—15	30	34	1.07 ± 0.14	1.54 ± 0.19
	u	16—40	30	10	1.27 ± 0.16	(1.45)
	u	12—40	60	44	1.15 ± 0.11	1.52 ± 0.16
	l	12—15	28	38	1.06 ± 0.14	1.41 ± 0.16
	l	16—40	25	8	0.70 ± 0.10	(1.07)
	l	12—40	53	46	0.89 ± 0.09	1.36 ± 0.14
Space-difference $C—M_1$ (in mm). Left side	u	12—15	29	34	1.61 ± 0.21	3.05 ± 0.37
	u	16—40	30	10	1.60 ± 0.21	(1.54)
	u	12—40	59	44	1.58 ± 0.15	2.77 ± 0.30
	l	12—15	26	37	1.55 ± 0.21	1.58 ± 0.18
	l	16—40	24	8	1.44 ± 0.21	(0.84)
	l	12—40	50	45	1.46 ± 0.15	1.48 ± 0.16

jaw the trend of the difference is the same, but here it may also be due to random variation (difference $= 0.83 \pm 0.49$ mm.).

With respect to the eventual effect of age, the comparison must evidently be based on the relatively limited age group constituted by the age 12—15 years. This is a disadvantage and it should, of course, be of more interest to examine older twins for whom the existing differences could be considered as more definite. This can, however, not be made on the present material because the number of older fraternal twins is too small. In the younger twins the standard deviation of the intrageminal differences is significantly higher in the fraternal than in the identical twins (table 35), in the upper, as well as the lower jaw (difference $= + 2.50 \pm 0.79$ mm. and 1.89 ± 0.58 mm. respectively). So the influence of heredity to the absolute space seems therefore to be proved. A reservation must be made, nevertheless, as it can be thought that the greater dissimilarities in the space in the fraternal twins as compared to the identical, depend upon the fact that the dissimilarities concerning extraction of the milk molars are more usual in the former than in the latter. The losses of deciduous teeth are now conditioned by the different growth of the permanent teeth and by caries. A milk tooth may, of course, be lost accidentally due to other reasons, but these two reasons ought to be the most common. Dissimilarities in the growth of permanent teeth should, to a great extent, be conditioned by heredity, and this, to some degree, is also true of caries as previously mentioned. One must, however, take into consideration that, in this respect, environmental dissimilarities are greater in the fraternal than in the identical pairs. The increased variation which is conditioned by dissimilarities in the losses of milk molars in fraternal twins should, therefore, to some extent depend upon environment. In other words, one cannot assume that environmental differences between identical

and fraternal twins are completely similar, and that the excess variation is dependent upon heredity only.

Space-difference for the whole dental arch (cases without missing teeth). The agreement between the size of the teeth and of the jaw has been determined by calculating the space-difference; this is defined as the absolute space minus the sum of the individual tooth-breadths within the examined region of the jaw. The space-difference naturally is not, just as little as the space, only dependent upon the size of the jaw. The number, size and inclination of the teeth has here, also, a more or less decisive influence. For example, the significance of the tooth-sizes is proved by the different examinations which have shown that crowding is more frequent with large teeth than with small teeth (*Lewis* and *Lehman*, 1932, *A. Lundström*, 1942, and *Seipel*, 1946).

The mean value of the difference between the left and right side in the space-difference is, as was true of the space, significant in the lower jaw in the older twins ($+0.56 \pm 0.14$ mm.). The agreement is also good between the left-right variation of the space, and that of the space-difference (in the upper jaw the difference in standard deviation is $+0.02 \pm 0.10$ mm., and in the lower jaw -0.04 ± 0.10 mm., see tables 34 and 36). This seems to confirm the conception that the deviation in the space between the left and right side depends only partly upon the deviations in the tooth-size between the halves of the body.

The space-difference in each half of the jaw is formed by the difference between the space and the sum of the tooth-breadths within the half of the jaw in question. This rule has been applied even if some of the teeth have been filled. The space-difference deviates, therefore, considerably from 0 only if the teeth within the half of the jaw are crowded or spaced. Thus, it is evident that if the deviation in the tooth-size between the left and right side generally cause a corresponding change in the space, then the variation should be less for the space-difference than for the

Table 36. **Comparison between variability between left and right side and variation in identical twins in regard to the space-difference in the dental arches (in mm). The variation is expressed in the standard deviation, σ, for the differences.**

σ_m of differences between double measurements on the same individual and σ_0 of intrageminal differences are calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the difference and n the number of pairs investigated.

σ_D is used when the mean of the differences show a significant deviation from 0. The formula then used is $\sqrt{\frac{\Sigma d^2}{n} - b^2}$, where b is the mean of the differences.

Type of variability	Type of twins	Differences between[1]	Age, years	Upper jaw		Lower jaw	
				No.	$\sigma \pm \varepsilon(\sigma)$	No.	$\sigma \pm \varepsilon(\sigma)$
σ_m		l — l	12—40	40	0.47 ± 0.05	39	0.60 ± 0.07
σ_m		r — r	12—40	40	0.54 ± 0.06	39	0.60 ± 0.07
σ_D	Id + Fr	l — r	12—15	88	1.12 ± 0.08	86	1.24 ± 0.09
σ_D	Id + Fr	l — r	16—40	57	1.25 ± 0.12	51	1.02 ± 0.10
σ_D	Id + Fr	l — r	12—40	145	1.18 ± 0.07	137	1.19 ± 0.07
σ_0	Id	l — l	12—15	28	2.00 ± 0.38	25	1.46 ± 0.21
σ_0	Id	l — l	16—40	29	1.17 ± 0.15	23	1.00 ± 0.15
σ_0	Id	l — l	12—40	57	1.60 ± 0.15	48	1.25 ± 0.13
σ_0	Id	r — r	12—15	28	1.80 ± 0.34	25	1.33 ± 0.19
σ_0	Id	r — r	16—40	29	1.22 ± 0.16	23	0.98 ± 0.14
σ_0	Id	r — r	12—40	57	1.56 ± 0.15	48	1.16 ± 0.12

[1] l = left side of the jaw from I_1 to M_1.
r = right side of the jaw from I_1 to M_1.

space. Naturally, this does not signify that the dissimilarities in tooth-size do not affect the space. In that case the variation should be greater for the space-difference than for the space. It seems, consequently, as if the effect of dissimilarities in tooth-size expressed itself more or less equally as dissimilarities in space, and as deviations in the form af crowding or spacing. As regards other factors that might be of decisive importance to the dissimilarity of the space-difference between the halves of the body, we refer here to the previous discussion concerning the space.

In view of the above mentioned, it is natural that the

space-difference shows an analogical difference as for the space, also as regards the comparison between the left-right and intrageminal variation in identical twins (table 36). Consequently no greater differences exist, and it is, therefore, evident that those factors which cause differences between identical pairs of twins are largely the same as those which cause the difference between the halves of the body, also as regards the space-difference.

With respect to the eventual influence of age, and the age distribution, the dissimilarities between identical and fraternal pairs of twins could be determined only on the younger twins (table 35). In the upper jaw, the intrageminal variation in the fraternal pairs of twins is significantly greater than in the identical (difference $= +2.22 \pm 0.74$ mm.). In the lower jaw the corresponding difference is probable ($= +1.18 \pm 0.53$ mm.). As pointed out for the space these differences need not depend only upon a direct genetical effect. They may also be caused indirectly through loss of deciduous teeth.

A difference in principle exists as to the effect of the tooth-size upon the space and upon the space-difference. We herewith touch the question to which extent genetical differences in the tooth-sizes cause a larger or smaller dental arch or give an increased risk of crowding and spacing. In view of the fact that the relatively small differences in the tooth-size between the left and right side only seem to be partially compensated by a change in the size of the dental arch, it seems improbable that the considerably greater genetical differences in the tooth-size could have any essential influence on the space of the jaw. It is naturally, nevertheless, possible that considerable differences in the size of the teeth imply that they occupy a larger region of the jaw than if the teeth, on the whole, were smaller. The variation depending upon such conditions cannot be measured by determining the differences between the halves of the jaw, because only smaller differences in the size exist here. This is why no positive statement can

be given. The relatively strong correlation, which exists in the population as regards the whole dental arch between the size of the teeth and the space, can partly, at any rate, have another cause (the correlation coefficients in the twin material have, as regards the connection between these characters, been calculated as $+0.72 \pm 0.05$ in the upper jaw, and $+0.51 \pm 0.08$ in the lower jaw). The probability is that the same genes affect both the characters to some extent. In other words, a tall individual has a large jaw as well as big teeth.

The fact that large teeth are more often crowded than small ones, which are instead more frequently spaced, requires a special explanation. This fact seems to indicate that there are special genes which affect the teeth but not the jaws, and vice-versa. The explanation of the distribution of crowding and spacing, for large and small teeth, should also partly be found in the random variation in the size of the teeth. This could, as mentioned before, give at least smaller variation in the tooth position if the teeth become somewhat larger or smaller than that which corresponds to the average effect of the genes.

Variation in the space and space-difference for sections of the dental arch. After having discussed those measurements that were obtained from the whole dental arches, we will now consider the figures from the different sections of the jaws. It must be emphasized then, that environmental factors of local nature, such as loss of deciduous teeth, ought to be of greater importance to the sections of the arches than to the whole dental arch. Since the 6-years molar is the first to erupt of the permanent teeth, this tooth constitutes, in a way, a hindrance to greater displacement in the total space. On the other hand, it is easy to conceive how extractions or dissimilarities in the period of eruption can cause local displacement of the teeth. For example, a lack of space in one identical twin is found in the anterior region, and in the other twin perhaps in that of the premolars. To which extent local

anomalies, in this way, are environmental or caused by genetic factors can, however, not be decided à priori. An investigation of these circumstances have been made, therefore, on two sections within the jaws, namely, the region

Table 37. **Mean difference, M_D, and standard deviation, σ_0, in mm of intrageminal differences of the arch-space from M_1 to M_1 for identical and fraternal twin pairs in groups without and with missing teeth.**

σ_0 is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the intrageminal difference and n the number of twin pairs.

Group	Identical twin pairs			Fraternal twin pairs		
	No.	$M_D \pm \varepsilon(M_D)$	$\sigma_0 \pm \varepsilon(\sigma_0)$	No.	$M_D \pm \varepsilon(M_D)$	$\sigma_0 \pm \varepsilon(\sigma_0)$
Upper jaw						
Pairs without missing teeth	60	1.86 ± 0.24	2.65 ± 0.24	44	4.50 ± 0.49	5.59 ± 0.60
Pairs with missing teeth of one twin	13	4.92	·	35	9.92 ± 1.11	12.12 ± 1.45
Pairs with missing teeth of both twins	19	4.21 ± 0.82	5.61 ± 0.91	15	6.08 ± 1.58	8.77 ± 1.60
Lower jaw						
Pairs without missing teeth	52	1.43 ± 0.17	1.87 ± 0.18	46	3.33 ± 0.34	4.09 ± 0.43
Pairs with missing teeth of one twin	11	3.61	·	35	7.77 ± 0.96	9.73 ± 1.16
Pairs with missing teeth of both twins	25	2.92 ± 0.55	4.05 ± 0.57	14	6.10	·

of the incisors (I_2—I_2), and a lateral region (C—M_1).

As regards the space of the front teeth, the values show (table 35) that dissimilarities, measured by the standard deviation of the differences are greater within fraternal pairs of twins than within identical (12—15 years of age), in the upper jaw (diff. = +1.41 ± 0.30 mm.) and probably also in the lower jaw (diff. = +0.56 ± 0.26 mm.). As regards the space-difference figures the differences are less pronounced and no difference in the standard deviation

can be proved between identical and fraternal pairs of twins in either jaw (diff. = $+0.47 \pm 0.24$ mm. in the upper and $+0.35 \pm 0.21$ mm. in the lower jaw). It seems, therefore, as if non-genetic factors have a relatively great influence concerning crowding and spacing in the section of the front teeth. This should, to some extent, be associated with the fact that random and environmental factors influence the inclination of these teeth (see below). As mentioned previously, one must also reckon with premature loss of deciduous teeth. In cases of crowding such losses naturally facilitate the adjustment of the front teeth to a more normal position, which signifies that the localisation of crowding can be displaced distally in the dental arch to those teeth which are later to erupt, namely, the canine or the second premolar. It is possible that rather great differences might occur in this way within the identical pairs of twins if only one twin has losses of such deciduous teeth, or if both have had extractions at very different ages.

In the side regions of the jaws (C—M_1) the space difference only was examined, and only on one side, (left). In the upper jaw the standard deviation of the intrageminal differences is, in this respect, significantly greater in the fraternal twins than in the identical twins (diff. = $+1.44 \pm 0.43$ mm.) while, on the other hand, in the lower jaw a good agreement is found between both types of twins (diff. = $+0.03 \pm 0.28$ mm.). That the space-difference in the side region of the lower jaw is strongly affected by environment is natural, considering that the deciduous teeth in this region are on an average 2—3 mm. broader than the corresponding permanent teeth. Crowding can, therefore, hardly occur in connection with anything other than premature loss of deciduous teeth. This need not signify that lack of space is, in itself, completely conditioned by extraction of the milk molars. It seems most probable that crowding of this type occurs mainly with general lack of space in the jaw, which, as in the upper jaw, will be dis-

placed from the front teeth to the premolars through loss of deciduous molars. In favour of this is the fact that when the space-difference in the whole jaw is concerned then the genetic factors seems to be of comparatively great importance, while, on the other hand, individual sections might be more influenced by environment.

Space and space-difference in cases with missing teeth. So far the investigation has concerned the conditions in pairs of twins without loss of permanent teeth. In the following, the space conditions in pairs with missing teeth will also be discussed. It is a commonly known fact that the space conditions of the teeth alter after extraction. The teeth tend to alter their position, firstly by a closure of the extraction space, and secondly by a more or less pronounced spacing in the rest of the dental arch. This is, illustrated by, among others, *Seipel* (1946) and *Björk* (1947), whose investigations are more exact than previous ones. It should, therefore, be of no interest to give the figures obtained from the twin-material in this respect. It need only be mentioned that the total space decreaces after tooth-extraction in such way as can be expected, and that it has been possible to establish spacing, of the other teeth, particularly in the lower jaw after losses of 6-years molars.

It is of more interest to investigate to which extent the intrageminal differences in the space-conditions might depend upon tooth-extractions. This was made by determining the standard deviation of these differences, and the mean difference partly in pairs without missing teeth, partly in pairs with missing teeth in one twin per pair and finally in pairs with missing teeth in both twins. It should be pointed out that a tooth being characterized as missing mostly depends upon the fact that it has been extracted but, though to a smaller degree, also upon congenital absence or such a deep impaction that the tooth is not even visible as a bulge on the alveolar process. Calculations have been made for the total space and the total space-difference (tables 37 and 38). The reason why the standard devia-

Table 38. **Mean difference, M_D, and standard deviation, σ_0, in mm of intrageminal differences of the space-difference from M_1 to M_1 for identical and fraternal twin pairs in groups without missing teeth, with missing teeth of one twin per pair and with missing teeth of both twins per pair.**

σ_0 is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the intrageminal difference and n the number of twin pairs.

Group	Identical twin pairs			Fraternal twin pairs		
	No.	$M_D \pm \varepsilon(M_D)$	$\sigma_0 \pm \varepsilon(\sigma_0)$	No.	$M_D \pm \varepsilon(M_D)$	$\sigma_0 \pm \varepsilon(\sigma_0)$
Upper jaw						
Pairs without missing teeth.....	59	1.84 ± 0.22	2.51 ± 0.23	44	3.33 ± 0.53	4.88 ± 0.52
Pairs with missing teeth of one twin	14	4.24	·	37	4.45 ± 0.66	6.02 ± 0.70
Pairs with missing teeth of both twins	21	2.38 ± 0.50	3.36 ± 0.52	15	4.66 ± 0.85	5.83 ± 1.06
Lower jaw						
Pairs without missing teeth.....	51	1.57 ± 0.20	2.11 ± 0.21	45	2.44 ± 0.35	3.40 ± 0.36
Pairs with missing teeth of one twin	12	2.03	·	34	4.42 ± 0.70	6.08 ± 0.74
Pairs with missing teeth of both twins	30	2.39 ± 0.48	3.58 ± 0.46	17	2.54 ± 0.78	3.22 ± 0.55

tion, as well as the mean deviation, were calculated in spite of the fact that they both express the same thing is that through this, a comparison can be made even with that part of the material which is too small for the calculations of the standard deviation. Such a comparison cannot be made exact with standard errors, but it gives nevertheless an idea of the situation.

One must naturally expect a greater difference in pairs with loss of teeth in one twin only, than in those pairs without lost teeth. This also appears to be the usual case. The differences should also be greater between twins who both have loss of teeth than in pairs without losses; for it is uncertain whether they have lost the same tooth (or

Table 39. **Standard deviation, σ_0, of intrageminal differences of width and length of dental arches in mm and of the length in per cent of width at M_1. Pairs without and with missing teeth.**

σ_0 is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the intrageminal difference and n the number of twin pairs.

Character	Jaw	Age, years	No. of pairs: Id	No. of pairs: Fr	Ident. twin pairs $\sigma_0 \pm \varepsilon(\sigma_0)$	Frat. twin pairs $\sigma_0 \pm \varepsilon(\sigma_0)$
Pairs without missing teeth						
Width of dental arch at P_1 (in mm)	u	12—15	28	30	0.92 ± 0.12	2.60 ± 0.34
	u	16—40	30	10	1.33 ± 0.17	·
	u	12—40	58	40	1.13 ± 0.10	2.60 ± 0.29
Width of dental arch at M_1 (in mm)	u	12—15	30	34	1.80 ± 0.23	2.80 ± 0.34
	u	16—40	30	10	1.82 ± 0.23	·
	u	12—40	60	44	1.77 ± 0.16	2.63 ± 0.28
Length of dental arch (in mm)	u	12—15	30	34	1.36 ± 0.18	3.08 ± 0.37
	u	16—40	30	10	1.24 ± 0.16	·
	u	12—40	60	44	1.28 ± 0.12	2.99 ± 0.32
Length in per cent of width at M_1	u	12—15	30	34	3.24 ± 0.42	7.64 ± 0.93
	u	16—40	30	10	4.65 ± 0.60	·
	u	12—40	60	44	3.94 ± 0.36	7.32 ± 0.78
Width of dental arch at P_1 (in mm)	l	12—15	22	35	1.28 ± 0.19	2.47 ± 0.30
	l	16—40	25	7	1.33 ± 0.19	·
	l	12—40	47	42	1.28 ± 0.13	2.37 ± 0.26
Width of dental arch at M_1 (in mm)	l	12—15	27	38	1.13 ± 0.15	2.83 ± 0.32
	l	16—40	25	7	1.56 ± 0.22	·
	l	12—40	52	45	1.32 ± 0.13	2.70 ± 0.28
Length of dental arch (in mm)	l	12—15	27	38	1.13 ± 0.15	2.02 ± 0.23
	l	16—40	25	7	0.92 ± 0.13	·
	l	12—40	52	45	1.01 ± 0.10	2.04 ± 0.22
Length in per cent of width at M_1	l	12—15	27	38	5.35 ± 0.73	9.46 ± 1.09
	l	16—40	25	7	5.20 ± 0.74	·
	l	12—40	52	45	5.18 ± 0.51	9.58 ± 1.01
Pairs with missing teeth of one twin						
Width of dental arch at P_1 (in mm)	u	12—40	12	33	·	2.66 ± 0.33
	l	12—40	12	29	·	2.76 ± 0.36
Pairs with missing teeth of both twins						
Width of dental arch at P_1 (in mm)	u	12—40	15	15	1.61 ± 0.29	3.39 ± 0.62
	l	12—40	30	15	1.61 ± 0.21	1.37 ± 0.25

teeth) even if this often may be the case. Furthermore, the loss may have occurred at different times which should cause increased differences particularly if the time for the smoothing-out has been short. The latter differences seem greater, if anything, than one would expect, as they seem to be almost the same as the differences within those pairs where only one twin has losses. However, the standard errors are great which is why this may be dependent upon random variation.

In this connection it should be pointed out that the greater differences which are found within pairs with extractions as compared to those in pairs without missing teeth, should not only be secondary results of loss of teeth. One must also reckon with the effect of extractions as a treatment in cases of crowding. If a more extreme crowding is found in only one twin per pair and who is treated for this by extraction, then the space-difference between the twins may, of course, firstly be primarily conditioned and not at all, or only to a slight degree, be result of loss of teeth. This selection should result in that the genetic effect calculated on pairs of twins without loss of teeth may become somewhat too low, as greater space-dissimilarities, resulting in extractions in only one of the twins, should mainly be found in fraternal pairs of twins.

Length, width and length in per cent of width at M_1 *of the dental arches* (table 39). As regards the genesis in crowding as well as in other malocclusions, it is of interest to study the width and length of the dental arches. For example, it is conceivable that hereditary crowding in the upper jaw arises particularly from deficiency in the lateral growth, while environmental crowding maybe arises from dental arches which are too short (migration forward of M_1 by loss of deciduous teeth). As to the dependence of the measurements upon local displacements it should naturally be of great value if some reliable method to reconstruct these existed. Those methods given in literature are how-

ever, too inexact for scientific use. By the aid of symmetry determinations, it is true, one can obtain a conception of the displacement of one side in relation to the other, but one cannot of course determine whether both sides are displaced. Consequently no such determinations have been made.

As no changes with age can be proved as to the dispersion of intrageminal differences in the material (table 39), it seems justifiable to compare the figures for the identical and fraternal pairs of twins of the sum of older and younger pairs. If one reckons with 3 times the standard deviation, differences of 3 to 4 mm. between identical twins occur for the width of the dental arch at P_1 in the upper and lower jaw. The standard deviation of corresponding differences at M_1 are approximately the same size in the lower jaw, while in the upper jaw they are significantly greater than that at P_1 in the same jaw (difference $= +0.64 \pm 0.19$ mm.). Thus, at M_1 in the upper jaw differences of maximum 5 to 6 mm. exist between identical twins. The length of the dental arch show differences up to about 4 mm. in the upper jaw, and about 3 mm. in the lower jaw. The differences in question depend only slightly on errors of measurements which, according to double determinations, are relatively small (see table 14, page 63). The effect of random differences in the tooth-size is probably also small particularly in view of the fact that it should disperse itself over the width as well as the length. Random variations in the inclination of the teeth might be of greater importance. In this way, deviations of individual teeth might particularly arise. One can occasionally find such a deviation in the form of linguo-version for one single tooth, for example M_1. Such a malposition can naturally primarily be relatively slight, but become accentuated by pressure from the teeth in the opposite jaw. Among environmental factors which have a probable effect can be mentioned the pressure on the head during delivery. This pressure has, according to *Dahlberg* (1926), been the cause

of the first born of identical twins having a somewhat longer and narrower head and face than the second born (see page 9). It is then possible that the first born, especially during difficult deliveries, acquires a somewhat narrower and longer dental arch than the second. If this is the case it should occur above all in the upper jaw which is exposed to pressure from the zygomatic arches. The influence of premature loss of deciduous teeth on their location has already been discussed. Probable migration forward after such losses causes naturally some decrease in the arch-width, and perhaps especially in its length. Changes, which could conceivably arise in these ways, in the width and length of the dental arch, naturally react, more or less, on the values for the shape of the dental arch expressed as the length in per cent of the width at M_1; in identical twins these figures show differences up to approximately 12 per cent in the upper jaw, and 15 to 16 per cent in the lower.

The importance of the genetic factors on the characters in question appears from the fact that the standard deviation of the intrageminal differences is significantly greater for the width, length and shape of their dental arches in the fraternal than in the identical twins. The differences within the fraternal pairs reach a maximum of 7 to 8 mm. for the width of the dental arches, for the length in the upper dental arch approximately 9 mm., and for the lower approximately 6 mm. Corresponding values of the shape of the dental arches are 22 per cent and 29 per cent for the upper and lower jaw respectively. Besides those possibilities of genetic influence, as mentioned in connection with the space-conditions of the dental arches, it can be stated that deviations in the shape of the teeth may be of slight influence and particularly in the lower jaw. The width of the dental arch in this jaw was measured from the lingual surfaces of the teeth, and if then one of the twins had larger teeth or especially arched lingual surfaces in relation to the other some width-differences

Table 40. **Standard deviation, σ_0, in mm[1] of intrageminal differences of the inclination of medial upper incisors for identical and fraternal twin pairs.**

σ_0 is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the intrageminal difference and n the number of twin pairs.

Age, years	No. of pairs		Identical twin pairs	Fraternal twin pairs
	Id	Fr	$\sigma_0 \pm \varepsilon(\sigma_0)$	$\sigma_0 \pm \varepsilon(\sigma_0)$
			Pairs without missing teeth	
12—15	30	34	0.47 ± 0.06	0.83 ± 0.10
16—40	30	10	0.51 ± 0.07	·
12—40	60	44	0.47 ± 0.04	0.82 ± 0.09
			Pairs with missing teeth of one twin	
12—40	14	37	·	0.86 ± 0.10
			Pairs with missing teeth of both twins	
12—40	21	15	0.51 ± 0.08	0.51 ± 0.09

[1] 1 mm = appr. 6.3°.

might occur which have nothing to do with the actual width.

The influence of tooth-extractions on the width and length of the dental arch at M_1 cannot be determined on the present material, because the losses which exist are mainly losses of M_1. As to the width at P_1 in the upper jaw there exists negligible and insignificantly greater dispersion for the intrageminal differences in pairs with extraction in one twin, and in both twins respectively (table 39). The dispersion in the lower jaw seems, on the contrary, to be less in fraternal pairs with losses in both twins, than in pairs without losses (difference = 1.00 ± 0.36 mm.). However, the standard error is great and it is quite possible that the differences are due to random variation. Such a difference might otherwise depend upon the fact that loss of teeth causes increased space whereby eventual malpositions of P_1 could be equalised.

Inclination of the upper medial incisors. The deviations

in the inclination of the upper incisors belong to the more pronounced malocclusions. The variation of the differences for this character in identical and fraternal twins appears from table 40. In the table the standard deviations

Table 41. **Standard deviation, σ_0, in mm of intrageminal differences in the height of the palatal vault of identical and fraternal twin pairs.**

σ_0 is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the intrageminal difference and n the number of twin pairs.

Age, years	No. of pairs		Identical twin pairs	Fraternal twin pairs
	Id	Fr	$\sigma_0 \pm \varepsilon(\sigma_0)$	$\sigma_0 \pm \varepsilon(\sigma_0)$
			Pairs without missing teeth	
12—15	30	34	0.98 ± 0.13	1.77 ± 0.21
16—40	30	10	1.10 ± 0.14	·
12—40	60	44	1.03 ± 0.09	1.96 ± 0.21
			Pairs with missing teeth of one twin	
12—40	12	34	—	2.73 ± 0.33
			Pairs with missing teeth of both twins	
12—40	17	14	0.83 ± 0.14	·

in mm. are given, in accordance with the method of measuring when registering the inclination of the teeth (see page 58). As it is difficult to obtain a concrete conception of the significance of such an indirect expression for the inclination, a calculation was made as to which inclination differences, measured in degrees, corresponds to 1 mm. on the measuring instrument whereby a figure of approximately 6.3° was obtained.

Any change with age in the dispersion of the intrageminal differences cannot be proved. Within the whole material of identical pairs of twins without missing teeth, differences are found within the pairs up to approximately 9°. Since errors of measurement are small (see page 64), the found differences are mainly real. It should however,

be pointed out that the measured deviations could be attributed to a slight rotation of the front teeth, and not to deviations in the longitudinal direction of the teeth (in cases of pronounced rotation, 12 cases, the value of the inclination is, for this reason, assigned to the left or right side only). To which degree the inclination differences must be ascribed to random factors during the growth of the jaws, for example in the form of primary deviations of the germs of the teeth, or are dependent on environmental factors, cannot, of course, be determined without special investigations. The significance of finger-sucking should, according to investigations, (see review of literature) be negligible within that interval of age dealt with here. In literature, the following view has been advanced, that premature loss of teeth in the lower jaw might influence the inclination of the upper front teeth. If growth forward of the lower front teeth is retarded due to losses, the lower lip might go up under the upper front teeth, causing thereby protrusion. This effect, should however be rare, and might possibly be considered if the over-bite is primarily large and thus it lies on the boundary of the lower lip getting room up under the upper front teeth.

The influence of genetic factors on the inclination of the incisors is shown by the fact that the standard deviation of the intrageminal differences is significantly greater in fraternal than in identical pairs. Thus, in the fraternal twins differences exist up to approximately 16°. The differences of inclination are partly connected with the general structure of the face, which is shown by *Björk*'s (1947) investigations, the inclination being dependent upon the existing degree of prognathy. The mechanism of the genes, i. e. to what extent the inclination is connected with those genes which govern the structure of the skeleton of the face, the balance between the outward and inward muscle-pressure, or the primary direction of the germs of the teeth, is naturally very difficult to decide. A muscle effect

through the lower lip may be secondarily conditioned by a hereditary postnormal position of the lower jaw.

Such a protruding effect should be particularly strong if the upper lip is short. If on the other hand, a long upper lip with strong tonus exists, an inward inclination may, instead, be the result. This conception is the classic explanation of the two main types of postnormal occlusion, probably first stated by *Angle* (1907), i. e. cases with protrusion (Angle's class II, division 1), and with retrusion (class II, division 2) of the upper front teeth.

The dissimilarities in the inclination of the incisors within the pairs of twins agree on the whole very well in pairs without, and in pairs with missing teeth (table 40). In the fraternal pairs, however, the standard deviation of the differences seems to be less within pairs with loss of teeth in both twins, than within pairs without losses, and pairs with losses in only one twin respectively (difference $= -0.31 \pm 0.13$ mm. and -0.35 ± 0.13 mm. respectively). This seems difficult to explain, and it is of course possible that the deviation is due to random variation; particularly when considering the fact that the number of pairs with loss in both twins (= 15 pairs) lies on the border of what is demanded for calculating the standard error.

Height of the palatal vault. The height of the palatal vault is determined at M_1 perpendicular to the occlusal plane represented by the central fissures of M_1, and the cutting edges of the medial incisors. The measurements include thus, the height of the tooth-crown which is why not only deviations in the shape of the palate, but also deviations in the tooth-sizes might be the cause of differences between twins. The found standard deviations of the intrageminal differences in the height of the palatal vault show that no appreciable changes in the size of the differences seem to occur after 12—15 years of age (table 41). Within the identical twin-pairs, differences occur from 0 up to approximately 3 mm. These differences are only to a minor degree dependent upon errors of measure-

ments, (see page 64). Certain differences might, however, be apparent for other reasons, namely through the fact that the different heights of fillings in 6-years molars may influence the measurements. Vertical deviations of the position in the medial incisors also might influence the height-value of the palate. Furthermore, the eventual migration forward of M_1, after extractions of deciduous teeth, may be of some influence, since the palatal height decreases in the forward direction. This is possibly also the cause why the dispersion of the intrageminal differences seems to be somewhat greater in twin pairs where one twin has losses of permanent teeth, than in pairs without losses. Deficiency in nutrition should only to a minor degree be responsible for the differences, because such a deficiency as a rule influences both twins, and besides, those differences found in this respect nowadays seem to be without any actual influence on the occlusion (see review of literature). The same is true of the other characters which one generally connects with food, and particularly with lack of vitamin D.

The influence of heredity on the palatal height appears from the fact that the standard deviations of the intrageminal differences are significantly greater in the fraternal than in the identical twins. The differences in the fraternal twins are maximally about 6 mm.

Sagittal occlusion. Among the malocclusions the sagittal deviations are perhaps of the greatest importance because of their frequency, and also due to those functional and, especially, aesthetic inconveniences which they might cause the individual. The aesthetic inconveniences are obviously the most important when the front teeth are concerned; the functional are greatest when the molars are concerned, but they are seldom important. Sagittal deviations could naturally be registered at any tooth in the dental arches, but one usually determines the occlusion at the first molars, and also frontally through the sagittal overbite. None of these measurements yield any reliable

Table 42. **Comparison between variability between left and right side and variation in identical twins in regard to the sagittal occlusion at M_1 (in mm). The variation is expressed in the standard deviation, σ, for the differences.**

σ_m of differences between double measurements on the same individual and σ_0 of individual and intrageminal differences are calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the difference and n the number of pairs investigated.

Type of variability	Type of twins	Differences between[1]	Age, years	No.	$\sigma \pm \varepsilon(\sigma)$
σ_m		l — l	12—40	36	0.52 ± 0.06
σ_m		r — r	12 - 40	35	0.49 ± 0.06
σ_0	Id + Fr	l — r	12—15	48	1.93 ± 0.20
σ_0	Id + Fr	l — r	16—40	25	1.85 ± 0.26
σ_0	Id + Fr	l — r	12—40	73	1.88 ± 0.16
σ_0	Id	l — l	12—15	19	2.76 ± 0.45
σ_0	Id	l — l	16—40	19	1.91 ± 0.31
σ_0	Id	l — l	12—40	38	2.35 ± 0.27
σ_0	Id	r — r	12—15	17	1.70 ± 0.29
σ_0	Id	r — r	16—40	18	1.78 ± 0.30
σ_0	Id	r — r	12—40	35	1.71 ± 0.20

[1] l = left side, r = right side.

information as to the actual relationship between the jaws because the measuring points as indicated above, are subjected to local influences. Perhaps one should preferably measure the relation between the dental arches at all teeth in which case the mean of the measurements would be relatively reliable. Such a method requires naturally a great amount of work because of the number of measurements to be taken as well as the calculations which must necessarily be carried out. In this work the registration has been made therefore, according to the usual method.

Similarly to the method employed for the tooth-breadth and the space-conditions, the left-right variation was determined for the sagittal occlusion at M_1 (table 42). In

this connection, younger and older individuals show good accordance with respect to the standard deviations of the differences. The figures show that rather large differences, up to 5 to 6 mm., might occur between the left and right side. These differences can only to minor degree be explained as conditioned by errors of measurement. According to what has been previously pointed out, the location of M_1 can be affected by random occurrences in the internal environment, influencing the tooth-size or the growth of the jaw, and further by environmental factors such as premature loss of deciduous teeth, one-sided masticatory functioning and possibly also by genotypic asymmetry.

The intrageminal variation in identical twins seems to be of approximately the same size as that between left and right side. Only on the left side of the identical pairs of twins there exists a somewhat higher standard deviation between the twins, but the difference may very well be due to random variation. It is therefore probable, that those differences found between the twins as regards molar occlusion depend mainly upon such causal factors which affect the individual halves of the jaw. This indicates that, as for example, dissimilarities in finger-sucking between identical pairs of twins have little influence.

The comparison between the variation in the identical and in the fraternal twins was made partly for the individual sides, and partly for the average between the left and right side (table 43). With respect to the latter, differences of up to 5 mm. occur in the identical twins, and in the fraternal of up to approximately 8 mm. The difference in the standard deviation is merely $= 0.84 \pm 0.41$ mm. which is why genetic factors seem to have a moderate influence only on the molar occlusion. For the individual sides there exist differences of analogic size. These results naturally do not mean that heredity has little influence on the more extreme, sagittal anomalies, because such anomalies occur only to a small degree in the material.

For the *sagittal overbite,* differences up to approximately

Table 43. **Standard deviation, σ_0, of intrageminal differences in different characters of the occlusion of the jaws for identical and fraternal twin pairs. Pairs without missing teeth.**

σ_0 is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the intrageminal difference and n the number of twin pairs.

Character	Age, years	No. of pairs		Iden. twin pairs	Frat. twin pairs
		Id	Fr	$\sigma_0 \pm \varepsilon(\sigma_0)$	$\sigma_0 \pm \varepsilon(\sigma_0)$
Sagittal occlusion at M_1, left side	12—15	19	26	2.76 ± 0.45	3.07 ± 0.43
	16—40	19	6	1.91 ± 0.31	·
	12—40	38	32	2.35 ± 0.27	3.04 ± 0.38
Sagittal occlusion at M_1, right side	12—15	17	26	1.70 ± 0.29	2.67 ± 0.37
	16—40	18	4	1.73 ± 0.30	·
	12—40	35	30	1.71 ± 0.20	2.77 ± 0.36
Sagittal occlusion at M_1, average[1]	12—15	19	26	2.08 ± 0.34	2.64 ± 0.37
	16—40	17	6	1.71 ± 0.29	·
	12—40	36	32	1.88 ± 0.22	2.72 ± 0.34
Sagittal overbite	12—15	24	27	0.89 ± 0.13	2.60 ± 0.35
	16—40	20	7	1.81 ± 0.29	·
	12—40	44	34	1.37 ± 0.15	2.87 ± 0.35
Vertical overbite	12—15	22	25	1.06 ± 0.16	1.67 ± 0.24
	16—40	20	6	0.76 ± 0.12	·
	12—40	42	31	0.92 ± 0.10	1.64 ± 0.21
Difference in archwidth between upper and lower jaw at P_1	12—15	19	24	0.93 ± 0.15	2.57 ± 0.37
	16—40	20	6	1.07 ± 0.17	·
	12—40	39	30	1.00 ± 0.11	2.55 ± 0.33
Difference in archwidth between upper and lower jaw at M_1	12—15	24	27	1.84 ± 0.27	2.32 ± 0.32
	16—40	20	6	0.96 ± 0.15	·
	12—40	44	33	1.49 ± 0.16	2.43 ± 0.30

[1] The average between left and right side was used if the molar occlusion could be measured on both sides, otherwise single values are included.

4 mm. exist in the identical twins which are only slightly dependent upon errors of measurement (see page 64). Firstly, these differences might be caused by random dissimilarities in the internal environment. It is also conceivable that the position of the fetus in the uterus is of some

importance, e. g. if its arms press on the upper or lower jaw. Fingersucking is perhaps also of some importance even if this factor mainly seems to affect the position of the deciduous teeth. Extractions of deciduous teeth in one jaw only is another factor which has been maintained as influencing the overbite so that it becomes larger in cases of extractions in the lower jaw only, and less in cases of extractions in the upper jaw. More exact investigations as regards this question indicate however, that this factor is of little importance (see review of literature).

In older identical twins the dispersion of the intrageminal differences seems to be greater than in the younger (the difference $= +0.92 \pm 0.32$ mm.). This result agrees with *Björk*'s investigations (see page 82) according to which the dispersion in the population of the sagittal overbite is greater in older, than in younger individuals even if this increase may naturally also depend on the fact that the effect of genetic factors increase with age. The increase of dispersion in the identical twins can be said to indicate that there are environmental factors which affect the sagittal overbite after 12—15 years of age. It is however, also possible that the difference is a result of the inclination of the upper front teeth, particularly as they are generally inclined forwards. A non-genetic difference in the overbite may, because of this, become perhaps more marked as the individual grows older.

With respect to the influence of age, the comparison between identical and fraternal twins must be made on the younger age-groups. The fraternal show considerably greater variation than the identical (the difference $= +1.71 \pm 0.37$ mm.), with differences within the pairs up to approximately 8 mm. As *Björk* (1947) has shown that deviations in the sagittal overbite are first and foremost conditioned by differences in the horizontal part of the lower jaw, and to a smaller degree dependent on deviations in the inclination of the teeth, this discovery indicates that

heredity determines to a rather high degree the former of these characters.

Vertical overbite. Deviation in the vertical overbite is naturally closely connected with the sagittal overbite. Differences within identical pairs of twins might amount to approximately 3 mm., and they are to a slight degree only dependent on errors of measurement (see page 64). No alteration with age of the size of the dispersion can be proved.

The dispersion of the intrageminal differences is significantly greater in the fraternal than in the identical twins, and might amount to 5 to 6 mm. As previously mentioned, it is probable that this result is mainly a secondary result of the genetic influence on the sagittal deviations.

Extractions of permanent teeth do not seem to be of great importance to the size of the differences in the sagittal or vertical overbite, since the standard deviation for the differences show fairly equal values in pairs without and with losses (in one twin per pair and in both twins respectively, see table 44). However, a certain displacement towards greater differences seems to exist in pairs with extractions, hence it is conceivable that significant differences could be proved on a larger material.

Differences in arch-width between the jaws. In identical pairs of twins intrageminal differences of approximately up to 3 mm. are found for the difference in the arch-width between the upper and lower jaw at P_1, and up to 4 to 5 mm. at M_1 in pairs without missing teeth (table 43). Differences of this kind must naturally arise through such causal factors which selectively might affect the arch-width in one jaw e. g. the random deviations in the germs of the teeth or the growth of the jaws. It has been previously emphasized, that the pressure affecting the head during delivery, particularly for the first born twin, possibly affects to a higher degree the upper jaw than the lower which is why this factor may also be of some importance. Migration forwards of M_1, or backwards of P_1 as

Table 44. **Mean difference, M_D, and standard deviation, σ_0, in mm of intrageminal differences of the sagittal and vertical overbite for identical and fraternal twin pairs in groups without and with missing teeth.**

σ_0 is calculated according to the formula $\sqrt{\frac{\Sigma d^2}{n}}$, where d is the intrageminal difference and n the number of twin pairs.

Group	Identical twin pairs			Fraternal twin pairs		
	No.	$M_D \pm \varepsilon(M_D)$	$\sigma_0 \pm \varepsilon(\sigma_0)$	No.	$M_D \pm \varepsilon(M_D)$	$\sigma_0 \pm \varepsilon(\sigma_0)$
Sagittal overbite						
Pairs without missing teeth	44	0.83 ± 0.15	1.37 ± 0.15	34	2.12 ± 0.33	2.87 ± 0.35
Pairs with missing teeth of one twin	13	0.98	·	40	1.26 ± 0.19	1.74 ± 0.19
Pairs with missing teeth of both twins	37	0.92 ± 0.16	1.34 ± 0.16	21	1.82 ± 0.35	2.45 ± 0.38
Vertical overbite						
Pairs without missing teeth	42	0.64 ± 0.10	0.92 ± 0.10	31	1.30 ± 0.17	1.64 ± 0.21
Pairs with missing teeth of one twin	13	0.92	·	38	1.21 ± 0.14	1.51 ± 0.17
Pairs with missing teeth of both twins	35	0.90 ± 0.12	1.16 ± 0.14	20	1.55 ± 0.23	1.88 ± 0.30

a result of extractions of deciduous teeth belong also to those factors which, through the backwards deviating form of the jaw, can be thought of as affecting the arch-width at the teeth in question.

In identical twins there exists for the width-difference at M_1 almost significantly smaller intrageminal variation in the older pairs of twins than in the younger (the difference $= 0.88 \pm 0.31$ mm.). This may perhaps depend upon the fact that the effect of the various environmental factors mentioned here are, to a certain degree, of temporary nature. It may happen that those tooth migrations caused by premature loss of deciduous teeth are to a certain extent reversible. However, it is also conceivable that the change with age is conditioned by a certain selection from the

group without missing teeth, as cases with more extreme deviations may be treated with extraction, especially after the age of 12 15 years.

In the fraternal pairs of twins the intrageminal differences, expressed by the standard deviation, are significantly greater for the width-difference at P_1, and almost significantly greater for the width-difference at M_1 than in the identical pairs. Thus the difference within the fraternal pairs of twins might amount to 7 to 8 mm. at P_1 as well as at M_1. Whether this is to be taken as a proof of the fact that different genetic factors affect the growth of the width in the upper dental arch as compared to that in the lower seems however doubtful, because deviations in the width-difference may be of a rather complicated nature. Firstly, the form of the teeth may be of slight importance because the width of the lower dental arch has been measured from the lingual surfaces of the teeth, and if then one of the twins has particularly arched lingual surfaces as compared to that of the other certain width-differences may arise which, strictly spoken, has nothing to do with the actual width. Furthermore, we must reckon with the effect of the genetic differences in the predispositions of caries. To the extent this leads to dissimilarities in extraction of the milk molars, greater dissimilarities concerning the width-difference may arise between fraternal twins as compared to identical twins. Further, a width-difference can be secondarily conditioned by other anomalies than the transversal. A postnormal occlusion usually causes a somewhat too narrow upper jaw in relation to the lower. The cusps of the teeth in the upper and lower jaw fit into the fissures in the opposite jaw, and cause an adjustment of the arches according to the existing position of the occlusion.

CHAPTER VIII.

CASES OF EXTREME MALOCCLUSIONS

In the previous chapter we examined the differences that are to be found in non-selected identical and fraternal twin pairs. It is obvious that these differences are usually manifestations of fairly moderate deviations from what are generally looked upon as being normal occlusion. Consequently it will be interesting to investigate more closely the cases showing more pronounced malocclusions. In the following a report will therefore be given of the pairs with the most serious malocclusions in the material for one of the twins irrespective of how the other twin may be with regard to this question. Malocclusions appear mainly in the form of crowding and spacing, saddle-formed upper jaws, maxillary premolars and molars in linguoversion to mandibular and postnormal occlusion with or without a deep overbite.

It is clear that individual cases do not prove very much. Similarities in identical twins may be accidental just as well as in the case of fraternal. A dissimilarity in identical twins may be due to genotypic asymmetry, even though it is not very likely. In the case of fraternal twins there may be a dissimilarity, which may be due both to genetic as well as non-genetic factors. There is a risk that descriptions of individual cases which are to be found in literature are selected particularly with a view to identical twins. A particular case of identical twins is published just on account of its striking similarity. In this material there is no question of any such selection, seeing that the most extreme cases in both groups are published, and consequently they are more suitable for comparison.

1. Pronounced *crowding* is to be found both in the upper and lower jaws, and in the following there is a short account of five identical (Id.) and five fraternal (Ft.) cases with such anomalies.

Id. 1. Sten and Stig S. (♂, age 13, fig. 9, from the Orthodentic Department of the Eastman Clinic). Sten has a complete space-deficit of —13.2 mm. in the upper jaw, while Stig has —12.1 mm. In the lower jaw they have

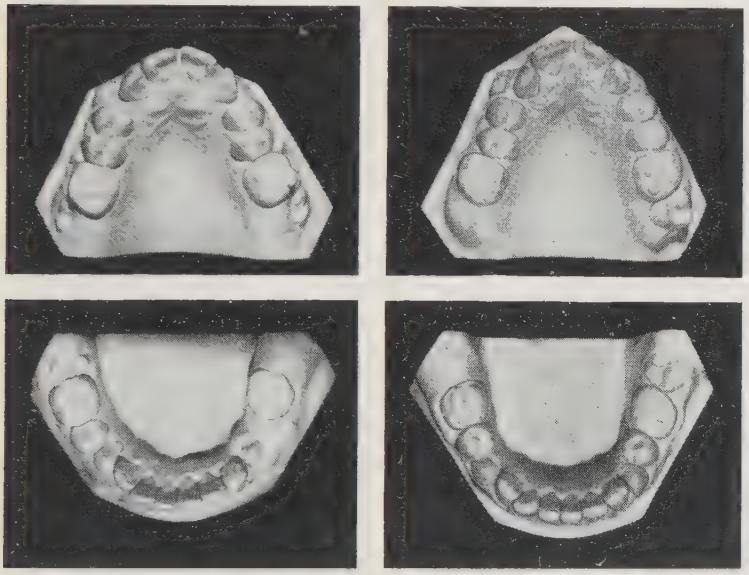

Fig. 9. Identical twins (13 years of age) with concordant, marked crowding, particularly in the upper jaw. Saddleformed upper jaws. Hypoplasia of the enamel on six years molars and front-teeth in both twins.

space-deficits of —5.1 and —6.8 mm. respectively. Both the boys have saddle-formed upper jaws, the space-deficit in both cases being confined to the canines in the upper jaw. These teeth have not yet erupted on the left hand side but are visible in the form of a bulge facially on the alveolar process, while those on the right hand have erupted above

the other teeth. In the lower jaw the premolars are crowded and Stig has a particularly pronounced space-deficit on the left. In both twins we see hypoplasia of the enamel in the first molars and in the medial incisors of the upper jaw, as well as in the incisors and canines of the lower jaw.

Id. 2. Ellen and Ingel T. (♀, age 12, fig. 10). Only Ellen shows a more pronounced space-deficit in the upper jaw (—9.2 mm.), while Ingel's space conditions are normal in

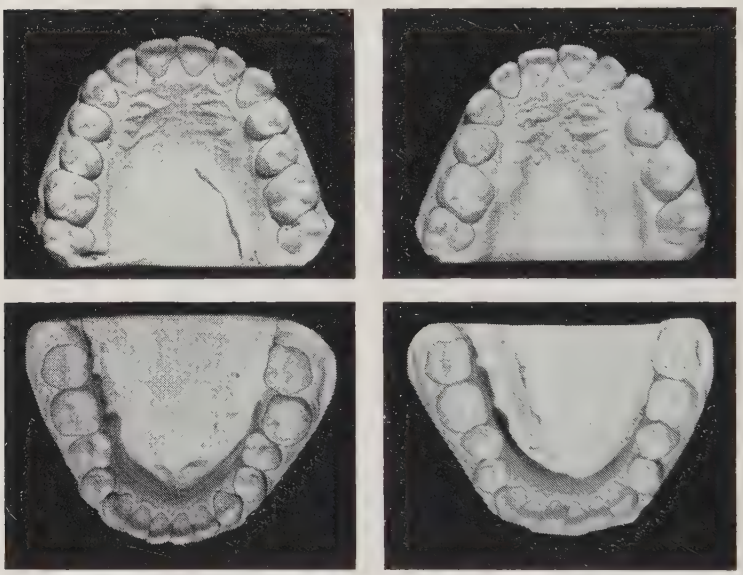

Fig. 10. Identical twins (12 years of age), one of whom has fairly normal dental arches, and the other showing pronounced crowding of second, upper premolars, which are impacted but visible as distinct bulges in the palate.

this jaw (+0.8 mm.). In the lower jaw the space-difference is —1.9 mm. and —2.4 mm. respectively. Ellen's crowding is confined to the second of the premolars in the upper jaw, which are impacted, but visible as distinct bulges in the palate. Unfortunately it has not been possible to obtain information concerning any premature loss of deciduous

molars, though this seems to be the most likely explanation of this type of crowding in only one of the identical twins.

Id. 3. Edit and Renate W. (♀, age 14, from the Orthodentic Department of the Dental School, fig. 11). In both these twins we find a considerable space-deficit, as well in the upper (—8.1 mm. and —7.4 mm.) as in the lower jaw (—6.8 mm. and —6.0 mm.). Edit's crowding in the upper jaw is mainly confined to the canines, while in the case of

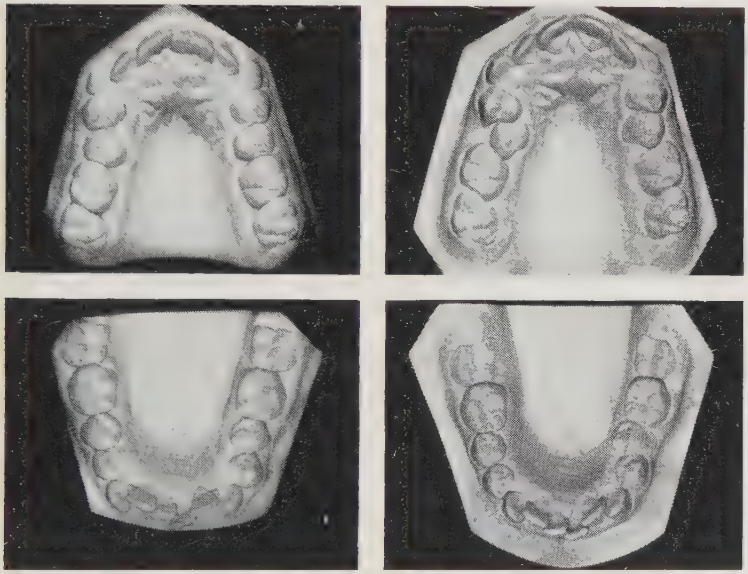

Fig. 11. Bimaxillary crowding of same degree, but partly different location in two identical twins (14 years of age).

Renate we find crowding of the canine on the left and the second premolar on the right. A displacement of this type in the locality of the crowding from the canine to the second premolar is of course natural after the premature loss of the second deciduous molar. Both the twins show a space-deficit in the lower jaw, which is mainly confined to the front teeth.

Id. 4. Lars and Olle P. (♂, age 14). Both the twins are

conspicuous on account of considerable space-deficit in both jaws (—6.8 mm. and —5.2 mm. in the upper jaw and —6.2 mm. and —5.8 mm. in the lower one respectively). The crowding is mainly frontal in the upper jaw, whereas in the lower one Lars shows fewer deviations than Olle with regard to the incisors, but on the other hand he has greater crowding at the second premolars.

Id. 5. Sven and Per-Olof L. (♂, age 14). Both twins show

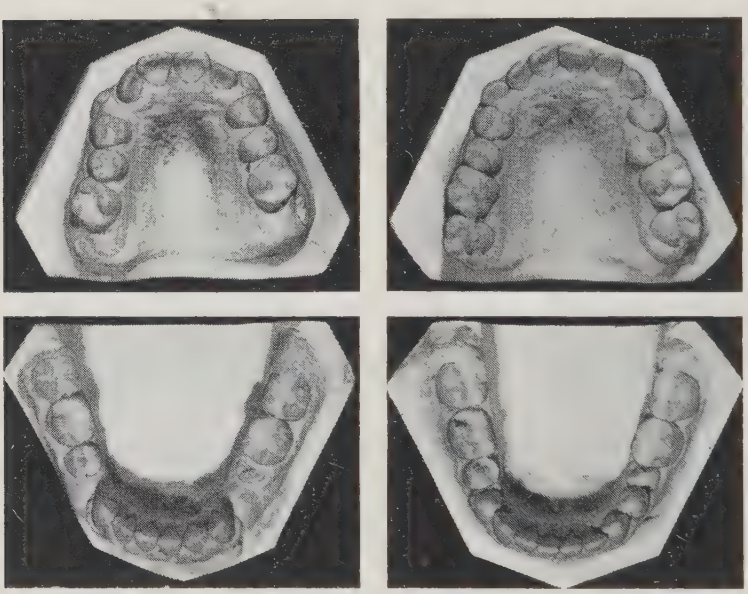

Fig. 12. Fraternal twins (13 years of age) with different crowding and arch-form in the upper jaw but similar crowding in the lower jaw.

a considerable space-deficit at the canines in the upper jaw, though there is spacing between the incisors with a well developed medial diastema. Sven's total space-deficit in the upper jaw is —6.7 mm., and Per-Olof's —2.2 mm. Both twins show a saddle-formed upper jaw. In the lower jaw we see a difference, first and foremost because in the case of Sven the eruption of the premolars has been completed, while both the premolars on the left and the first

premolar on the right have not yet erupted in the case of Per-Olof. The fact that Per-Olof has a surplus of space of +2.9 mm. in the lower jaw, while Sven, on the other hand, snows a space-deficit of —1.7 mm. may possible be due to Per-Olof's having recently shed the comparatively broad deciduous molars. Both the twins show pronounced hypoplasia of the enamel on all the four first molars and also from canine to canine in both jaws. This pair of twins reminds us very much of Id. 1 as far as tooth-position in the upper jaw is concerned and the place for the hypoplasia of the enamel, a coincidence worthy of note, even though it is naturally not possible to draw any conclusions.

Ft. 1. Sonja and Karin S. (♀, age 13, fig. 12). In both these twins the crowding of the teeth is fairly strongly pronounced in the premolar regions of the lower jaw with —5.1 mm. and —7.6 mm. respectively. The premolars are partly under eruption in the lower jaw. Sonja shows considerably less upper jaw (an extreme crowding of the canines) than Karin (the space differences being —6.0 mm. and —0.6 mm. respectively), which also appears in the occlusion to the lower jaw, where Sonja shows linguoversion of the upper right second premolar and the first molar and cusp-to-cusp occlusion in a facio-lingual direction of the upper left first molar.

Ft. 2. Kerstin and Inger F. (♀, age 30). Both of these twins show a bimaxillary crowding (—3.0 mm. and —4.5 mm. respectively in the upper jaw and —3.1 mm. and —2.4 mm. in the lower one), though they differ in character particularly in the upper jaw, as Kerstin has somewhat strongly rotated incisors and canines, whereas Inger's crowding, on the other hand, is confined solely to the canines, which are impacted with crowns directed towards the palate. In both cases the crowding in the lower jaw appears in the form of slight deviations of the front teeth, especially in the case of Kerstin (fig. 13).

Ft. 3. Åke and Gösta B. (♂, age 13). Åke has a certain frontal crowding in the upper jaw (space-deficit of —2.1

mm. at the incisors) as well as considerable crowding in the lower, particularly at the right canine and the second left premolar (total space-deficit in the lower jaw = —6.9 mm.). The crowding in the front of the upper jaw is counterbalanced to a certain extent by the fact that the second right diciduous molar has not been shed, thus producing a space surplus at this tooth as compared with the permanent tooth on the left side with 0.9 mm. Gösta's

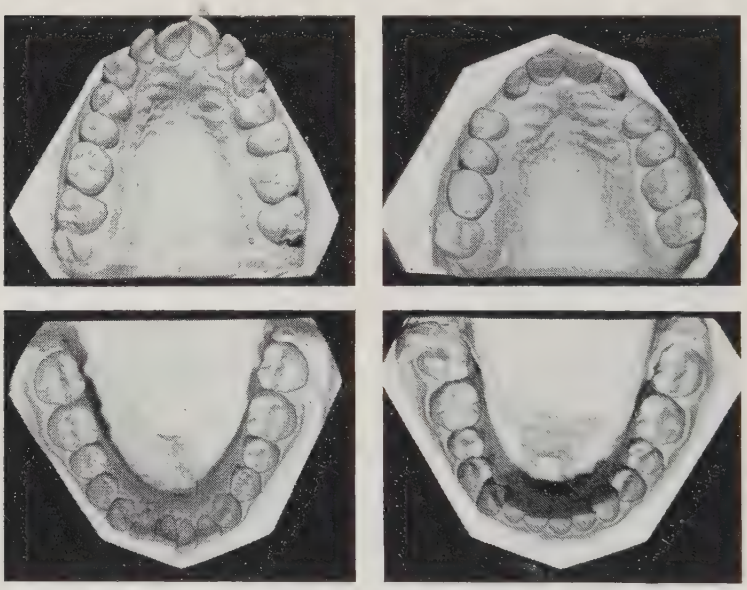

Fig. 13. Fraternal twins (30 years of age) with bimaxillary crowding, but of different character, particularly in the upper jaw, as one of them has rotated incisors and canines and the other crowded, impacted canines.

spacing seems to be practically speaking normal, with a space difference of +1.1 mm. in the upper jaw and —0.4 mm. in the lower. There is a slight crowding (—0.9 mm.) at the second, lower, left premolar which will in all probability disappear when the tooth is fully erupted.

Ft. 4. Gösta and Bo B. (♂, age 15, fig. 24). On the whole

Gösta shows normal spacing in the upper jaw (+0.2 mm.), which is so distributed that there is a certain crowding in the premolar regions, while there is some spacing between the incisors. In the lower jaw there is a space-deficit (—6.8 mm.), which is fairly evenly distributed in the arch. Bo presents a normal upper arch on the whole with a surplus of +2.7 mm., but the lower jaw is somewhat crowded (—2.3 mm.), especially at the right canine.

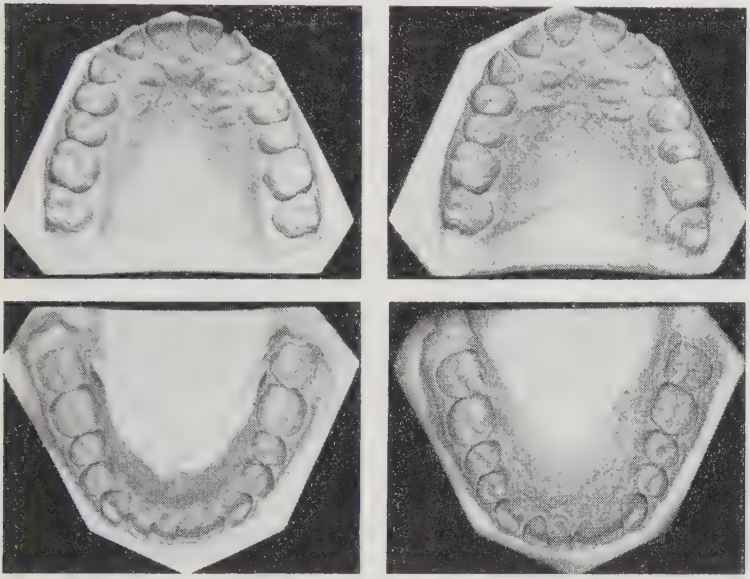

Fig. 14. Identical twins (14 years of age) with similar surplus of space in both jaws.

Ft. 5. Mats and Lars L. (♂, age 16). Mats shows a space-deficit in both jaws (—1.5 mm. and —5.9 mm. respectively). In the upper jaw the crowding is mainly confined to the incisors, which are rotated and partly cover each other, while in the lower jaw it is more evenly distributed in the arch. Lars shows almost normal spacing (—0.3 mm. and —1.9 mm. respectively), except for the medial incisors

in the upper jaw, which are somewhat rotated and at the left second premolar, which is lingually deviated in connection with a space-deficit of —2.4 mm.

2. As a contrast to the cases of crowding it may be of interest to give also an account of the more pronounced cases with surplus of space.

Id. 6. Lutz and Gerhard L. (♂, age 14, fig. 14). There is a rather considerable surplus of space in both twins from

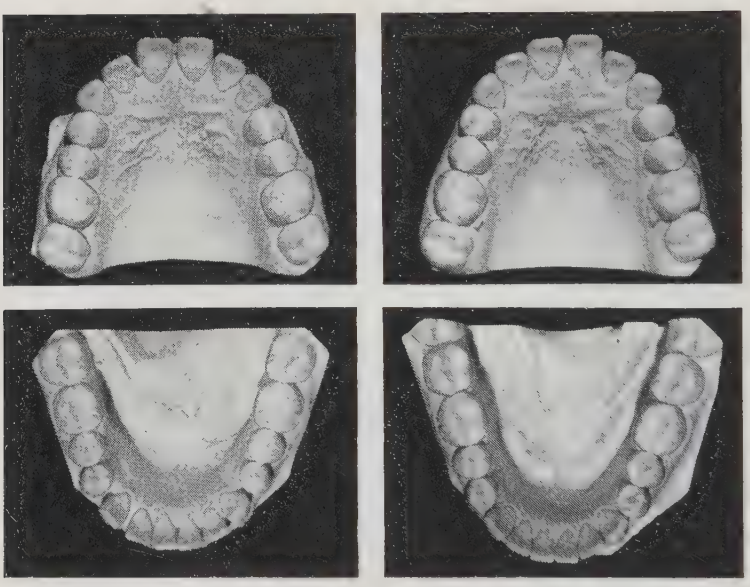

Fig. 15. Identical twins (16 years of age) with surplus of space in both jaws, though more marked in one of them.

canine to canine with +8.1 mm. and +5.5 mm. in the upper jaw and with +4.7 mm. and +5.0 mm. in the lower.

Id. 7. Cecilia and Agneta von S. (♀, age 16, fig. 15). There is a surplus of space in the jaws of both twins, though it is more marked in the case of Agneta (+3.7 mm. in the upper and +6.3 mm. in the lower jaw) than it is in Cecilia (+2.8 mm. and +1.2 mm.). The difference in the lower jaw may be temporary and attributed to the fact that Ce-

cilia's lower wisdom teeth are fully erupted, whereas Agneta's are not as yet visible. The doctor who confined the mother of these twins issued a definite report concerning different placenta for the two of them. Despite this fact, there seems hardly any doubt as to the diagnosis, as the twins were so exactly alike that their father as well as their friends often mistook one for the other, and even the colour of their eyes and the lines of their ears were alike.

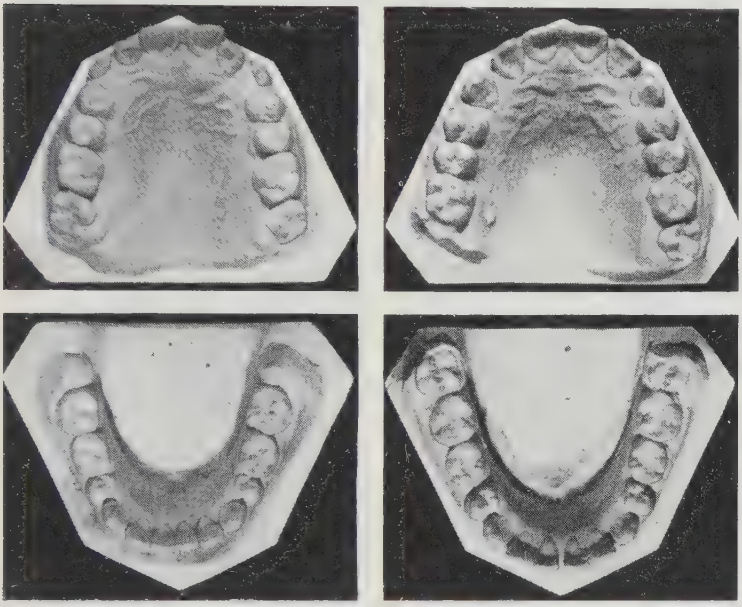

Fig. 16. Fraternal twins (12 years of age), one of which with fairly normal space conditions and the other with pronounced surplus of space.

Even the shape of the teeth was exactly the same, to the smallest detail.

Id. 8. Bertil and Kurt J. (♂, age 14). Both twins show a surplus of space in both jaws, with +5.0 mm. and +3.1 mm. in the upper and +1.1 mm. and +3.8 mm. in the lower. The spaces between the teeth in the upper jaw are

fairly evenly distributed from the left to the right canine. Bertil's are to be found in the lower jaw between the canine and the first premolars, and Kurt's on either side of the canines.

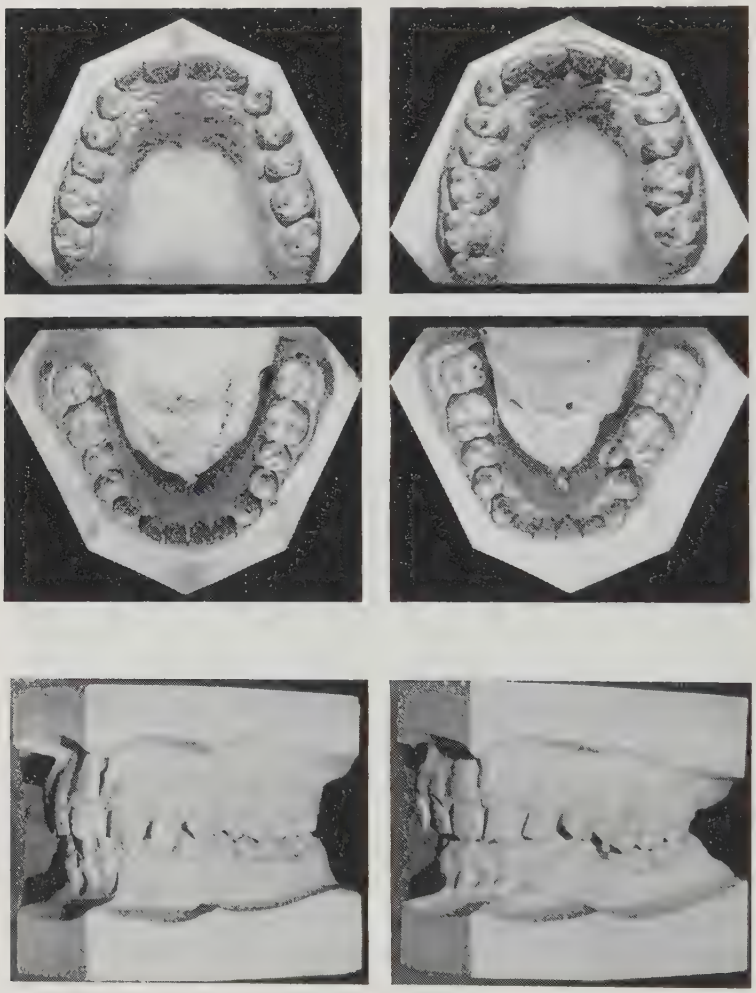

Fig. 17. Fraternal twins (15 years of age) with differences especially in the space-conditions and in the vertical overbite.

Ft. 6. Arne and Tore K. (♂, age 12, fig. 16). Arne shows a strongly pronounced spacing with a surplus of +6.1 mm. in the upper and +10.1 mm. in the lower jaw, while Tore has a slight crowding (—2.0 mm.) of the incisors in the upper and a space surplus of +5.2 mm. in the lower jaw. Neither of the twins has shed the second deciduous molars in the lower jaw.

Ft. 7. Kalle and Lasse G. (♂, age 12). Both the twins

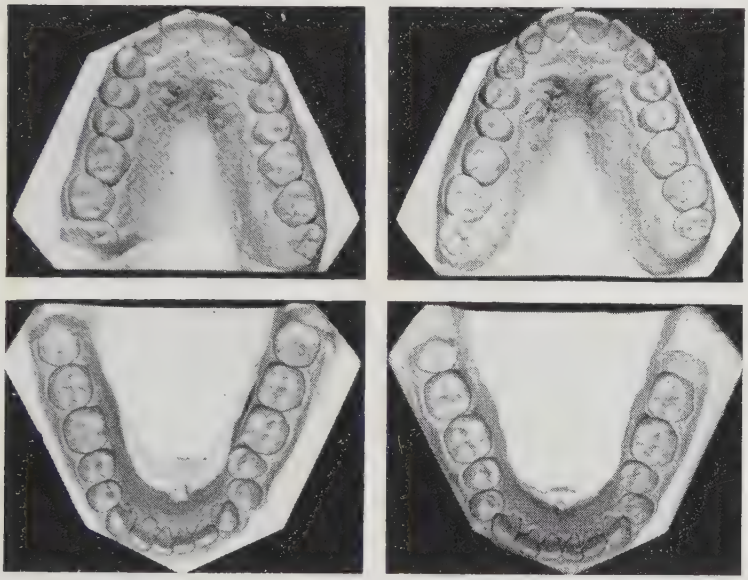

Fig. 18. Identical twins (19 years of age), both showing a saddle-formed upper jaw.

show a surplus of space in the upper and lower jaws, Kalle with +7.6 mm. and +3.0 mm. and Lasse +4.1 mm. and +2.6 mm. Lasse has not yet shed his second deciduous molars in the upper jaw, which may account for the surplus of space here.

Ft. 8. Mari and Marianne O. (♀, age 15, fig. 17). Mari shows a pronounced spacing from the left to the right second premolar in the upper jaw and from the left to the

right first premolar in the lower jaw. The space surplus is +6.1 mm. in the upper and +6.3 mm. in the lower jaw. Marianne, on the other hand, shows normal spacing in the upper (—0.2 mm.) and crowding in the lower jaw (—4.8 mm.), the lower second premolar deviating in a lingual direction.

3. *Saddle-formed upper jaws* are to be found in twins without missing teeth in 10 identical (all concordant) and

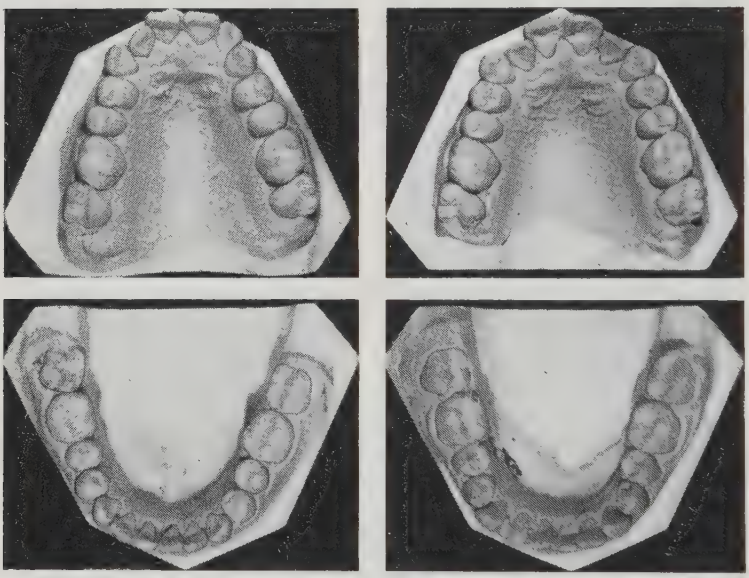

Fig. 19. Fraternal twins (18 years of age) with different arch-form, one showing narrow saddleformed upper jaw and the other normal arch-form. Both twins have moderate crowding, especially in the upper jaw.

in 9 fraternal pairs (two concordant and 7 discordant). Examples of more pronounced cases (one identical, Id. 9 and one fraternal Ft. 9) will be seen in fig. 18 and in fig. 19.

4. *Linguoversion of maxillary premolars and molars to mandibular.* If we define linguoversion as being the occlu-

sion when at least two premolars or molars on one side bite with the teeth of the upper jaw in or inside the cusp-to-cusp occlusion against the lower jaw, then the number of twin-pairs with linguoversion of maxillary premolars

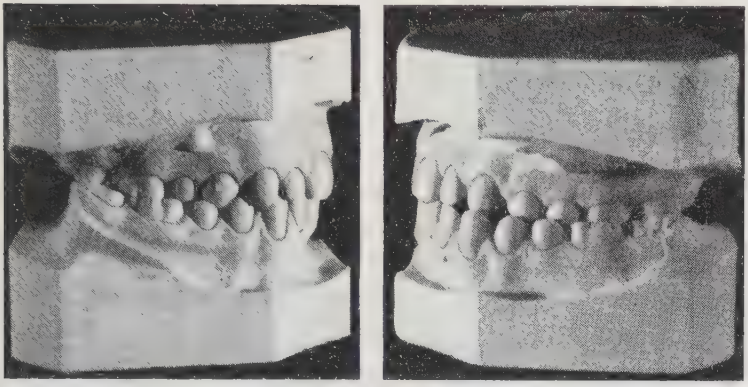

Fig. 20. Identical twins (15 years of age) with similar linguoversion of maxillary premolars and molars to mandibular.

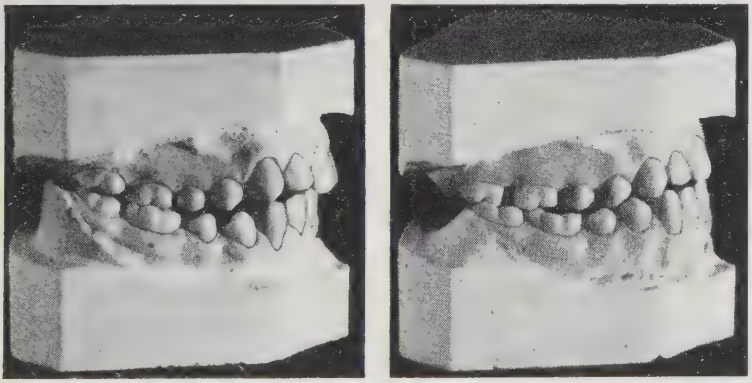

Fig. 21. Fraternal twins (13 years of age) with similar linguoversion of maxillary premolars and molars to mandibular.

and molars to mandibular are 5 in the identical and 6 in the fraternal twins (among pairs without missing teeth). In the case of the identical twin-pairs four are concordant and one is doubtful, while one of the twins shows linguo-

version for only one tooth (upper right first molar), the other having both the second premolar as well as the first molar in linguoversion on both sides. Of the fraternal pairs 4 are concordant and 2 discordant. The co-twins with the most pronounced linguoversion of maxillary premolars and molars to mandibular, one of which is identical (Id. 10) and one fraternal (Ft. 10) are to be found in fig. 20 and fig. 21.

5. Cases of considerable *sagittal overbite* are not uncommon in the material. The following pairs show the most pronounced anomalies of this type.

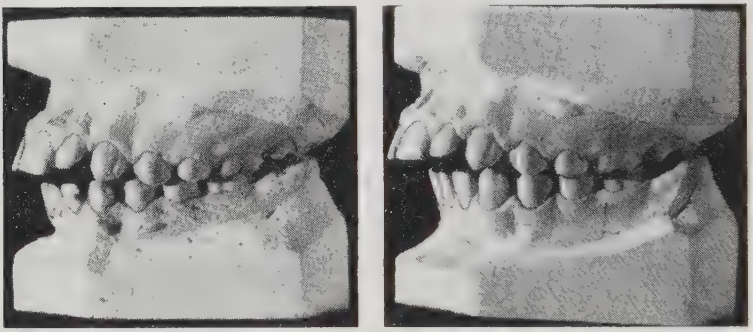

Fig. 22. Identical twins (12 years of age) with pronounced sagittal overbite. One of the twins has normal molar occlusion on both sides, while the other is normal on the right and postnormal on the left side.

Id. 11. Ingegerd and Karin C. (♀, age 12, fig. 22). Ingegerd has a sagittal overbite of +8.0 mm. and Karin of +6.0 mm. Both twins show an open bite with a negative overbite of —1.8 and —2.0 mm. respectively. Both of them also show a marked protrusion of the incisors of the upper jaw, the angle between the occlusion plane and the facial surfaces of the incisors being for both 67° or about 12° less than the arithmetical mean.[1] The sagittal molar occlusion

[1] According to calculations made from 155 twins (identical + fraternal) without missing teeth the arithmetical mean is 78.8° ±0.38°, one twin having been examined in each pair. The standard deviation in the same material is 4.4°.

in the case of Ingegerd is normal on the right and postnormal (—3.5 mm.) on the left (one cusp-width), while Karin has normal molar occlusion on both sides.

Id. 12. Peter and Göran L. (♂, age 16, fig. 23). Peter has a pronounced postnormal occlusion with a sagittal overbite of +7.5 mm. and also distal occlusion at the first molars with one cusp-width (—3.6 mm.) on the left and a half on the right (—2.7 mm.). The vertical overbite is almost nil (—0.7 mm.). Göran, on the other hand, shows an almost edge-to-edge occlusion at the incisors with a sagittal overbite of +0.5 mm. and a vertical overbite of 0 mm. The

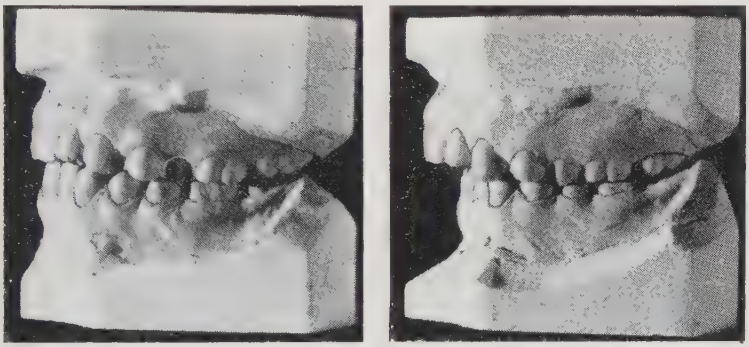

Fig. 23. Identical twins (16 years of age) with great difference in the sagittal overbite, possibly due to prolonged thumb-sucking up to 15 years of age of one of the twins, while the other got out of this habit when he was about 5 or 6 years old.

molars on both sides present a prenormal occlusion of half a cusp-width (+2.1 mm. on the left and +2.3 mm. on the right). The reason for this difference may be that Peter used to suck his thumb until he was about 15, whereas, according to a statement, Göran got out of the habit much earlier (when he was about 5 or 6, as far as his mother could remember).

Id. 13. Margareta and Birgitta B. (♀, age 16). Margareta's sagittal overbite is +7.0 mm. and Birgitta's +6.0 mm., the vertical being +1.6 and +1.5 mm. respectively. The in-

clination of the incisors is about the average in both. The molar occlusion is normal in both on the left and postnormal on the right (—4.5 mm. and —2.1 mm. respectively).

Id. 14. Olof and Lars J. (♂, age 12). Both twins show a considerable sagittal overbite (+7.0 mm. and +6.5 mm. respectively). The vertical overbite is +4.0 mm. and +3.3 mm. The inclination of the upper incisors toward the occlusal plane is about the average in both. Olof's molar occlusion is normal, though it is slightly postnormal on both sides in the case of Lars (—0.7 mm. on the left and —0.5 mm. on the right).

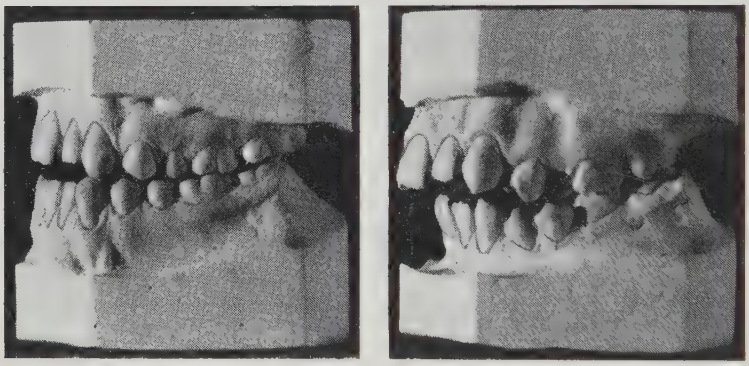

Fig. 24. Fraternal twins (15 years of age) with great difference in the sagittal overbite. Both twins show an open bite.

Id. 15. Sven and Gunnar G. (♂, age 13). There is a marked sagittal overbite (+6.5 mm. and +6.0 mm.) in both twins, the vertical, however, being normal (+2.9 mm. and +2.2 mm.). There is a slight protrusion of the incisors of the upper jaw in both, the deviation from the mean value for the inclination of these teeth being 7° and 6° respectively.

Ft. 4. Gösta and Bo B. (♂, age 15, fig. 24).[1] In Gösta the

[1] This pair has already been mentioned concerning a marked crowding in the lower jaw in one of the twins. (Gösta.)

sagittal overbite is +9.0 mm. and in the case of Bo only 1.0 mm. Both show an open bite frontally without any contact between the upper and lower jaws, in the case of Bo from the left to the right second premolar (vertical overbite = —4.1 mm.) and in Gösta for the same teeth with the exception of the left canines, the cusp-points of which contact each other (vertical overbite = —3.1 mm.). Gösta shows a slight protrusion of the upper incisors with a deviation from the mean value of 5° and of 3° when compared with Bo. Gösta's molar occlusion is slightly postnormal (—0.9 mm. on the left and —1.5 mm. on the right), whereas in the case of Bo it is just the reverse, i. e. a

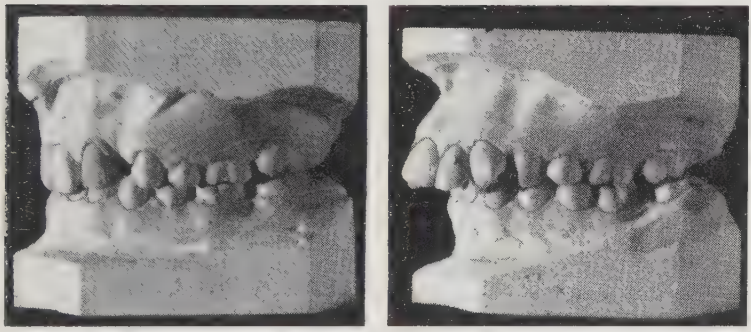

Fig. 25. Fraternal twins (30 years of age) with pronounced difference in sagittal relationship between the jaws, both at the frontteeth and laterally (see also fig. 13).

certain prenormal occlusion (+1.2 mm. and +4.7 mm.). Both twins show saddle-formed upper jaws, thus exhibiting a bite usually associated with rickets. No hypoplasia of the enamel, however, indicates that either of the twins has had this disease.

Ft. 2. Kerstin and Inger F. (♀, age 30, fig. 25).[1] Kerstin has a marked sagittal (+8.5 mm.) and vertical (+4.9

[1] This pair has already been mentioned in connection with a marked crowding, particularly in the case of one of the twins. (Kerstin.)

mm.) overbite, whereas Inger's sagittal overbite is small (+1.0 mm.) but her vertical unusually large (+6.8 mm.). There is a fairly considerable difference in the inclination of the incisors as compared with the occlusal plane, Kerstin having an angle of 73° and Inger 87°. Kerstin has on both sides post-normal occlusion of a whole cusp-width at the first molars (—4.9 mm. on the left and —5.2 mm. on the right), while Inger shows normal molar occlusion on the left (—0.4 mm.) and a post-normal occlusion of half a cusp-width on the right (not measurable owing to an amalgam crown on the upper first molar).

Ft. 11. Erik and Axel S. (♂, age 16). The sagittal overbite here is +8.0 mm. and +5.0 mm. and the vertical +2.1 mm. and +1.0 mm. In both the inclination of the upper incisors shows only slight deviations from the arithmetical mean. The molar occlusion is postnormal in the case of Erik (—5.1 mm. on the left and —5.2 mm. on the right) and almost normal in Axel (+0.5 mm. and —1.4 mm. respectively).

Ft. 12. Åke and Gösta B. (♂, age 13). Åke's sagittal overbite is +7.8 mm. and Gösta's +2.5 mm. The vertical overbite is +2.2 mm. and +3.1 mm. Åke's incisors are somewhat more protruded (the angle as compared with the occlusal plane is 72°—73°) than in the case of Gösta (79°). Åke's molar occlusion is normal and so is Gösta's on the right, but the left shows slight prenormal occlusion (+1.8 mm.). Åke shows postnormal occlusion to the width of a whole premolar at the first premolars on the left as well as crowding at the second premolar, in consequence of which it is likely that the normal occlusion at the first molars on this side is of a local character due to a mesial migration of the left first lower molar after a premature loss of a deciduous molar.

Ft. 13. Claes and Sven B. (♂, age 15). The values for the sagittal overbite are +7.3 mm. and +4.3 mm. and vertically we have +6.5 mm. and +5.0 mm. The inclination of the incisors is in good agreement with the arithmetical mean

in the case of Claes, while Sven shows a slight retrusion of 3° in these teeth. In Claes the molar occlusion is post-normal on both sides (—4.9 mm. and —4.6 mm.), whereas Sven shows a deviation on one side only (+0.9 mm. and —4.0 mm.).

The above report shows both similarities and dissimilarities in both identical and fraternal co-twins when it concerns more extreme malocclusions. The dissimilarities, however, seem to be decidedly in the preponderance in fraternal twin-pairs, something that points to the importance of heredity when considering the origin of such anomalies. We find rather marked differences in the case of two identical twin-pairs, one with regard to the space at the second premolar in the upper jaw and the other with reference to the sagittal occlusion. These differences may be due to the premature loss of the deciduous molars and to prolonged finger-sucking (up to the age of 15).

CHAPTER IX.

SIGNIFICANCE OF GENETIC AND NON-GENETIC FACTORS AS REGARDS THE TOOTH-BREADTH AND THE OCCLUSION

In the preceding chapters we have endeavoured to elucidate the influence of heredity, and heredity and environment together, using the empirical values of the differences in identical and fraternal twin-pairs as starting-point. We will now venture further into the theoretical field, and aided by these differences calculate that variation which genetic and non-genetic factors should produce in themselves, that is, the variation we should get if the different groups of factors alone caused a variation in population and the other factors were constant. Among non-genetic factors are also included those factors which cause differences between the left and right side. We will, when possible, also give a measurement of this variation. Finally, we vill calculate the ratio between the variations caused by genetic and non-genetic factors. In these calculations we use the formulae given in the chapter on statistical methods.

In order to avoid lengthy explanations, and to obtain brief terms we will utilize the term *"asymmetric variation"*, in the following for that variation which is obtained from the differences between the left and right side after having subtracted that variation conditioned by errors of measurement. The asymmetric variation should mainly arise through random variation during development but it can also express environmental and genetic factors with unilateral effect. Furthermore, that variation which is ob-

tained from the differences between identical twins after subtraction of that variation, which is obtained from the differences between the left and right side, we term *"environmental variation"*. This term is not completely adequate, because not only the variation in question confines itself to environmental factors with symmetric effect, but also because it may, to a minor degree, be due to random variation in factors which have nothing to do with environment in the usual sense of the word. The sum of the asymmetric variation and the environmental variation is termed the *"non-genetic variation"*. Finally, as *"genetic variation"*, we term that variation which is obtained from the differences between fraternal twins after subtracting the variation calculated from the differences in identical twin-pairs. However, it must already be pointed out here, that in certain cases this variation can be conditioned by environmental factors, namely, in those cases where fraternal twins have a more varying environment than the identical. In the following we will discuss some characters from this viewpoint.

Tooth-breadths. As calculations of the standard deviation between the left and the right side, due to reasons previously mentioned (see pages 92—93) have only been carried out for I_1, I_2 and C in the upper jaw, the analysis must also be confined to these teeth when calculating the asymmetric and environmental variation (table 45). In view of the results already mentioned, it is natural that the asymmetric variation is larger for I_2 ($= 0.25 \pm 0.02$ mm.) than for I_1 and C ($= 0.12 \pm 0.01$ mm. for both teeth). As regards the tooth-breadths, the asymmetric variation should as mentioned, be firstly conditioned by random variation in the internal environment, probably mainly during the embryonic stage. On the other hand external environmental factors for instance in the form of unilateral pressure against the jaw, should during this stage be of minor importance, because of the protecting cover constituted by the jaws. It is impossible to say

Table 45. **Comparison between asymmetric, environmental variability and geneti variability as regards I_1, I_2 and C in the upper jaw. The variability is expressed i the standard deviation, σ, in mm, and the coefficient of variation, V, in per cent.**

$\sigma_{1:1}$ for asymmetric variability is calculated according to the formula $\sqrt{\sigma_D^2 - \sigma_m^2} \cdot \frac{1}{\sqrt{2}}$ where σ_D is the standard deviation of differences between left and right side in identica twins and σ_m the standard deviation of differences between double measurements on th same individual.

$\sigma_{1:2}$ for environmental variability is calculated according to the formula $\sqrt{\sigma_0^2 - \sigma_D^2} \cdot \frac{1}{\sqrt{2}}$ where σ_0 is the standard deviation of intrageminal differences of identical twin pairs.

Tooth	Error of measurement		Asymmetric variability		Environmental variability		Genetic variability		Quotients		
	No.[1]	$\sigma_3 \pm \varepsilon(\sigma_3)$	No.[2]	$\sigma_{1:1} \pm \varepsilon(\sigma_{1:1})$	No.[3]	$\sigma_{1:2} \pm \varepsilon(\sigma_{1:2})$	No.[4]	$\sigma_2 \pm \varepsilon(\sigma_2)$	$\frac{\sigma_{1:1}}{\sigma_{1:2}}$	$\frac{\sigma_2}{\sigma_{1:1}}$	$\frac{\sigma_2}{\sigma_{1:2}}$
I_1	40	0.05±0.004	91	0.12±0.01	89	0.07±0.02	93	0.34±0.03	1.7	2.8	4.6
I_2	39	0.07±0.006	88	0.25±0.02	83	0.05±0.03	98	0.35±0.03	5.0	1.4	6.5
C	37	0.04±0.003	81	0.12±0.01	77.5	0.06±0.02	87	0.25±0.02	2.0	2.1	3.8
		$V_3 \pm \varepsilon(V_3)$		$V_{1:1} \pm \varepsilon(V_{1:1})$		$V_{1:2} \pm \varepsilon(V_{1:2})$		$V_2 \pm \varepsilon(V_2)$	Standard error of the above quotients		
I_1		0.59±0.05		1.41±0.12		0.82±0.24		4.00±0.35	±0.15	±0.25	±0.4
I_2		1.06±0.09		3.78±0.30		0.76±0.45		5.24±0.45	±0.50	±0.12	±0.6
C		0.52±0.04		1.57±0.13		0.79±0.26		3.27±0.26	±0.17	±0.17	±0.3

[1] Number of double measurements.
[2] Number of differences between left and right side.
[3] Number of identical twin pairs.
[4] Number of fraternal twin pairs.

whether any genotypic asymmetries occur for the teeth, but it is naturally quite possible. Thus, it is conceivable that the great dispersion of I_2 in particular might be dependent on this fact. As previously mentioned (page 100), it is, however, also possible that this circumstance is connected, with the genes having a lower penetrance for I_2 than for I_1 and C, or with the internal environment varying more at the former than at the two latter teeth.

The environmental variation is considerably smaller than the asymmetric, and further it is approximately equally as large for all three investigated teeth (for $I_1 = 0.07 \pm 0.02$ mm., for $I_2 = 0.05 \pm 0.03$ mm. and for $C = 0.06 \pm 0.02$ mm.). This variation is an expression of fundamental differences between identical pairs of twins, and it may depend upon such environmental differences as for example dissimilarities in nutrition, or with respect to diseases, between the twins. Such differences might however, also arise through random variation during the early development of the fetus.

When calculating the genetic dispersion, the differences between the mean value for the left and right side have been employed while on the other hand, the asymmetric and environmental variation is calculated on the differences between the individual sides. From a theoretical viewpoint the dispersion obtained by employing the mean value should become somewhat smaller than that obtained by employing the values of one side only. That the differences are insignificant appears from table 17, page 77. It seems probable that the difference which may occur affects the variation of errors of measurement and the asymmetric variation, but on the other hand not the environmental and genetic variations which are expressions of factors having symmetric effects. Hence it does not seem necessary to make special calculations of the genetic variation for the individual side.

The genetic variation is obviously greater than the two types of non-genetic dispersions (the standard deviation of heredity is for $I_1 = 0.34 \pm 0.03$ mm., for $I_2 = 0.35 \pm 0.03$ mm. and for $C = 0.25 \pm 0.02$ mm.). This variation should be purely genetically conditioned, as the fraternal twins show if anything, smaller environmental dissimilarities than the identical during the age when the teeth develop (see page 100). However, it is improbable that because of this the genetic variation is appreciably too small,

since the variation due to environment seems to be small even in the identical twins.

In view of the dissimilarity in the tooth-size (the arithmetical mean is for $I_1 = 8.5$ mm., for $I_2 = 6.6$ mm., and for $C = 7.6$ mm.) it is also of interest to investigate the coefficients of variation. As to the asymmetric variation the exceptional position of I_2 is revealed here even more clearly; whereas the environmental variation shows good agreement between all the three teeth. The genetic variation is possibly greater for I_2 than for the other two teeth. This is at least the case as regards the difference between I_2 and C, which is clearly significant (diff. $= 1.97 \pm 0.52$ per cent). Thus, the greater variation for I_2 as compared to the other teeth does not seem to be explained only by a higher asymmetric variation for this tooth than for the other. The difference seems to be found in the genetic mechanism also. This circumstance indicates that genes are found which affect this tooth in particular.

In the preceding we have accounted for the division of the total variation according to different groups of factors. By placing these values in proportion to each other, quotients are obtained giving unitary expressions of the conditions. However, it must be remembered that a quotient may be large either because the denominator is small, or because the numerator is large.

The quotient between the asymmetric and environmental variation for $I_1 = 1.7$, for $I_2 = 5.0$ and for $C = 2.0$, the higher quotient for I_2 depending upon the fact that the asymmetric variation for this tooth is so great. For the same reason a lower quotient between genetic variation and asymmetric variation is obtained for I_2 ($= 1.4$), than for I_1 and C ($= 2.8$ and 2.1 respectively). The quotient between genetic and environmental variation is highest for I_2 ($= 6.5$), after which follows I_1 ($= 4.6$) and C ($= 3.8$). The difference between I_2 and C is significant ($= 2.7 \pm 0.71$) and is connected with the different values of the

Table 46. **Comparison between non-genetic and genetic variation as regards the tooth-breadth (average between left and right side). The variation is expressed in the standard-deviation, σ, in mm and in the coefficient of variation, V, in per cent.**

Tooth	Error of measurement		Non-genetic stand. dev.		Genetic stand. dev.		Heredity		
							Non-heredity		
	No.[1]	σ_3	No.[2]	σ_1	No.[3]	σ_2	$\frac{\sigma_2}{\sigma_1} \pm \varepsilon\left(\frac{\sigma_2}{\sigma_1}\right)$	$V_1 \pm \varepsilon(V_1)$	$V_2 \pm \varepsilon V_2$
Upper jaw									
I_1	38	0.05	91	0.13	94	0.34	2.7 ± 0.44	1.5 ± 0.18	4.0 ± 0.47
I_2	40	0.07	90	0.20	98	0.35	1.7 ± 0.32	3.0 ± 0.38	5.2 ± 0.71
C	40	0.04	87	0.11	87	0.25	2.2 ± 0.41	1.5 ± 0.18	3.3 ± 0.42
P_1	38	0.09	62	0.08	73	0.28	3.3 ± 1.04	1.2 ± 0.29	3.9 ± 0.53
P_2	37	0.08	53	0.13	60	0.26	2.0 ± 0.51	1.9 ± 0.36	3.8 ± 0.64
M_1	37	0.12	45	0.16	45	0.30	1.9 ± 1.32	1.6 ± 0.36	3.0 ± 0.61
Lower jaw									
I_1	40	0.04	93	0.09	91	0.20	2.3 ± 0.40	1.7 ± 0.23	3.8 ± 0.49
I_2	40	0.06	95	0.08	94	0.26	3.1 ± 0.61	1.4 ± 0.26	4.4 ± 0.53
C	40	0.05	93	0.10	95	0.21	2.2 ± 0.40	1.4 ± 0.21	3.2 ± 0.40
P_1	39	0.10	80	0.08	85	0.25	3.2 ± 0.96	1.1 ± 0.29	3.5 ± 0.50
P_2	35	0.10	62	0.15	67	0.26	1.7 ± 0.45	2.1 ± 0.40	3.5 ± 0.62
M_1	37	0.15	43	0.18	47	0.38	2.1 ± 1.40	1.6 ± 0.40	3.5 ± 0.67

[1] No. of double measurements
[2] No. of identical twin pairs.
[3] No. of fraternal twin pairs.

genetic variation, which, as mentioned, is larger for I_2 than for C.

For all the investigated teeth (I_1—M_1) a calculation of the genetic and the whole non-genetic variation has been made (table 46). In these calculations the mean value between the left and right side has, as far as possible, been employed (in 75—85 per cent of the pairs, it has been possible to calculate the difference between the two mean values). This should, as mentioned, result in that the non-genetic variation becomes somewhat smaller than if the values of the individual sides were employed, since that part of the non-genetic variation ascribed to dissimilarities

between left and right side must decrease when the mean value is used. To which extent this can affect the values may be found by comparing the sum of the asymmetric and the environmental variation in table 45 (which are ascribed to the individual side), with the non-genetic variation obtained for the mean values. The former standard deviations are for I_1, I_2 and C in the upper jaw 0.14 mm., 0.26 mm. and 0.13 mm., while for the latter 0.13 mm., 0.20 mm. and 0.11 mm. The difference is thus negligible. For I_2, which shows the greatest deviation the difference is only 0.055 ± 0.025 mm. It is natural that the difference is greatest for I_2 since this tooth has the greatest asymmetric variation.

The coefficient of variation for non-heredity lies between 1 and 2 per cent for the majority of the teeth. The upper I_2 shows the highest value, approximately 3 per cent and this value seems to be higher than the values of all the other teeth except possibly P_2 in the lower jaw, the value of which (2.1 per cent) shows good agreement with that of I_2. The genetic dispersion is greater than the non-genetic, and shows for the majority of teeth coefficients of variation between 3 and 4 per cent. The quotient between the genetic and non-genetic standard deviation varies between 2 and 3 for the majority of teeth. It may be observed that upper I_2 and lower P_2 have the lowest quotients which is of interest, since these teeth are known as being especially labile as regards size and shape. The material is however, small and it is possible that these differences are caused by random variation.

It has been previously shown (chapter V), that the dispersion in the population, measured by the standard deviation, is on an average 1.4 times greater than the dispersion in fraternal twins. The question is now; to which extent is this difference dependent upon a greater non-genetic, or a greater genetic dispersion in the population. In view of the fact that the non-genetic variation is mainly of the asymmetric variation type, which should be the

Table 47. **Genetic standard deviation, σ_2 (in mm) and genetic coefficient of variation, V_2, (in per cent) in tooth-breadth (mesio-distal width) in the population and the relation between heredity and non-heredity, calculated on the assumption that the standard deviation of non-heredity, σ_1, (cf. table 47) is the same in the twins as in the population.**

Tooth	Genetic standard deviation in the population σ_2	Genetic coefficient of variation in the population $V_2 \pm \varepsilon_{V_2}$)	Heredity / Non-heredity $\frac{\sigma_2}{\sigma_1}$
		Upper jaw	
I_1	0.49	5.8 ± 0.47	3.9
I_2	0.57	8.6 ± 0.76	2.8
C	0.41	5.4 ± 0.46	3.7
P_1	0.43	6.0 ± 0.55	5.1
P_2	0.36	5.2 ± 0.54	2.8
M_1	0.40	3.9 ± 0.55	2.5
		Lower jaw	
I_1	0.30	5.7 ± 0.49	3.3
I_2	0.29	4.9 ± 0.51	3.5
C	0.31	4.6 ± 0.48	3.2
P_1	0.28	3.9 ± 0.49	3.6
P_2	0.39	5.4 ± 0.55	2.5
M_1	0.42	3.8 ± 0.60	2.4

same within the population as in twins, it seems probable that the difference in question is dependent essentially on the genetic dispersion being greater in the population than in fraternal twins, in whom it is limited because they have the same parents. If a calculation of the quotient between heredity and non-heredity could be made in the population, higher values than those found in twins would probably be obtained. In view of this, it might be of interest to calculate the maximum values of this quotient in the population, where the difference in question is accordingly assumed to be conditioned by heredity only (see page 68). The standard deviations and coefficients of variation obtained appear in table 47. The figures show a genetic effect

which is on an average, 3—4 times grater than the non-genetic. The deviation from the twin values are therefore, quite moderate. As the figures were calculated under the supposition of an extreme assumption which cannot be completely true, it seems probable that the twin-values give nevertheless, a fairly correct expression of the conditions also within the population.

It is somewhat remarkable that the heredity, for such a character as the tooth-breadth, has not a greater effect as compared with those non-genetic factors, which through random variation during the development of the teeth seem to be in this connection of the greatest importance. It has already been pointed out that the great dissimilarities between the left and right side, for upper I_2 especially, may possibly depend on the occurrence of genotypic asymmetries. It is therefore necessary to make a certain reservation against the results obtained as to the ratio between heredity and non-heredity, because of the possibility that some differences which have been reckoned as non-genetic are, in reality, genetic.

Space for the teeth in the jaws. When investigating the space-conditions in the dental arches we will, similarly to the tooth-breadth, divide the variation in fraternal twins according to different groups of factors. We will firstly discuss the significance of different groups of factors constituting the total variation, and after which endeavour to find unitary expressions of the ratio between them by making quotients (table 48).

The division of the total variation for the sum of the tooth-breadths within the jaw-half ($I_1 - M_1$) shows a variation of 0.31±0.04 mm. in the upper jaw due to asymmetrically affecting factors, while symmetrically affecting factors in environment give a variation of 0.35±0.26 mm., and in heredity 1.59±0.27 mm. The corresponding figures in the lower jaw are 0.28±0.05 mm., 0.18±0.19 mm., and 1.45± 0.20 mm. respectively. Accordingly, the genetic dispersion clearly predominates the asymmetric and environmental

Table 48. **Comparison between asymmetric and environmental variability and genetic variability as regards sum of tooth-breadths, space and space-difference in the dental arch from I_1 to M_1 for cases without missing teeth. The variability is expressed in the standard deviation, σ, in mm.**

$\sigma_{1:1}$ for asymmetric variability is calculated according to the formula $\sqrt{\sigma_D^2 - \sigma_m^2} \cdot \sqrt{\frac{1}{2}}$, where σ_D is the standard deviation of differences between left and right side in identical twins and σ_m the standard deviation of differences between double measurements on the same individual.

$\sigma_{1:2}$ for environmental variability is calculated according to the formula $\sqrt{\sigma_0^2 - \sigma_D^2} \cdot \sqrt{\frac{1}{2}}$ where σ_0 is the standard deviation of intrageminal differences of identical twin pairs.

Age, years	Error of measurement		Asymmetric variability		Environmental variability		Genetic variability		Quotients		
	No.	$\sigma_3 \pm \varepsilon(\sigma_3)$	No.	$\sigma_{1:1} \pm \varepsilon (\sigma_{1:1})$	No.	$\sigma_{1:2} \pm \varepsilon (\sigma_{1:2})$	No.	$\sigma_2 \pm \varepsilon(\sigma_2)$	$\frac{\sigma_{1:1}}{\sigma_{1:2}}$	$\frac{\sigma_2}{\sigma_{1:1}}$	$\frac{\sigma_2}{\sigma_{1:2}}$
***Upper jaw**: Tooth-breadth*											
12–40	26	0.19 ± 0.03	49	0.31 ± 0.04	23	0.35 ± 0.26	21	1.59 ± 0.27	0.9 ± 0.67	5.1 ± 1.09	4.1 ± 3.46
Arch-space											
12–15			88	0.80 ± 0.07	28	1.08 ± 0.27	34	1.69 ± 0.32	0.7 ± 0.20	2.1 ± 0.44	1.6 ± 0.49
16–40			57	0.83 ± 0.08	29	0.43 ± 0.15	10	·	1.9 ± 0.70	·	·
12–40	40	0.26 ± 0.03	145	0.81 ± 0.06	57	0.79 ± 0.12	44	1.83 ± 0.26	1.0 ± 0.17	2.3 ± 0.36	2.3 ± 0.33
Space-difference											
12–15			88	0.70 ± 0.07	28	1.09 ± 0.26	34	1.42 ± 0.30	0.6 ± 0.07	2.0 ± 0.47	1.3 ± 0.42
16–40			57	0.82 ± 0.09	29	(neg.)	10	·	∞	·	·
12–40	39.5	0.36 ± 0.04	145	0.75 ± 0.06	57	0.75 ± 0.12	44	1.42 ± 0.22	1.0 ± 0.18	1.9 ± 0.33	1.9 ± 0.42
***Lower jaw**: Tooth-breadth*											
12 - 40	29	0.29 ± 0.04	63	0.28 ± 0.05	29	0.18 ± 0.19	31	1.45 ± 0.20	1.6 ± 1.71	5.2 ± 1.17	3.2 ± 8.78
Arch-space											
12–15			86	0.78 ± 0.07	25	0.22 ± 0.14	38	1.44 ± 0.22	3.5 ± 2.30	1.8 ± 0.33	6.4 ± 4.28
16–40			51	0.75 ± 0.08	23	(neg.)	8	·	∞	·	·
12–40	40	0.27 ± 0.03	137	0.77 ± 0.06	48	neg.)	46	1.21 ± 0.18	∞	1.6 ± 0.26	∞
Space-difference											
12–15			86	0.77 ± 0.08	25	0.45 ± 0.16	38	1.14 ± 0.23	1.7 ± 0.63	1.5 ± 0.30	2.5 ± 0.52
16–40			51	0.66 ± 0.09	23	(neg.)	8	·	∞	·	·
12 - 40	39.5	0.42 ± 0.05	137	0.73 ± 0.07	48	0.11 ± 0.10	46	1.13 ± 0.18	6.6 ± 0.64	1.5 ± 0.29	10.1 ± 11.4

variation. It should be observed that the asymmetric and environmental variations agree rather well with each other contrary to I_1, I_2 and C in the upper jaw, where the asymmetric variation is significantly greater than the environmental variation. This difference may depend on random variation, because the standard error of the environmental variation for the jaw-half is relatively large. A calculation made from the variation coefficients indicates nevertheless, that it is the asymmetric variation which is smaller for the jaw-half than for the individual teeth. The asymmetric variation for the jaw-half is 0.65± 0.08 per cent for the upper jaw, and 0.64±0.15 per cent for the lower, while the corresponding figures for I_1, I_2 and C are 1.41±0.12, 3.78±0.30, and 1.57±0.13 per cent. This difference between the variation of the sum of the tooth-breadths, and that of the individual teeth must depend on the fact that a certain correlation exists. It is, however, impossible to determine how strong this correlation may become as the material is too small.

The division of the total variation for the space and space-difference must be made on the younger twins (12—15 years), because the intrageminal differences possibly diminish with age (see table 35), and also the number of older, fraternal twin-pairs is too small for the calculation in this age-group. In the upper jaw the asymmetric variation of the space within the half of the dental arch (I_1—M_1) is 0.80±0.07 mm., the environmental variation 1.08±0.27 mm., and the genetic variation 1.69±0.32 mm. In the lower jaw the asymmetric variation is 0.78±0.07 mm., the environmental variation 0.22±0.14 mm., and the genetic variation 1.44±0.22 mm. The difference between the jaws seems to be that environmental variation is greater in the upper than the lower jaw (difference = +0.86±0.30 mm., cf. table 48).

The values of the space-difference agree rather well with those of the space. Thus in the upper jaw the asymmetric variation is 0.70±0.07 mm., environmental variation 1.09±

0.26 mm., and genetic variation 1.42±0.30 mm., while the corresponding figures in the lower jaw are 0.77±0.08 mm., 0.45±0.16 mm., and 1.14±0.23 mm. It has already been emphasized that the great variation of the space-differences shows that the tooth-size cannot have a completely decisive influence on the arch-space which accordingly, is determined to a certain degree by the position of the teeth. As to the asymmetric variation this also appears from the fact that the space-variation is clearly greater than the variation of the tooth-size (diff. = 0.49±0.08 mm. in the upper, and 0.50 ± 0.09 mm. in the lower jaw). On the other hand, no such difference can be proved for the environmental and genetic variation, even if this fact, of course, does not prevent that such differences might be proved on a larger material. It must be pointed out that the values of the environmental dispersion may not give a correct expression of the effect of symmetrically affecting environmental factors. If genotypic asymmetries exist with a tendency of occurring on the same side in identical twin-pairs, the environmental variation naturally becomes too small.

The slight difference which seems to exist between the tooth-size and the space in the genetic variation (diff. = —0.10 ± 0.42 mm. in the upper jaw, and +0.01 ± 0.30 mm. in the lower jaw), appears to indicate that indirectly affecting factors, such as premature loss of deciduous teeth, cannot be of any greater influence of the genetic space-variation. It is most natural of course, that the direct genetic effect is equally as great for the sum of the tooth-breadths as for the space, and if therefore, such indirectly affecting factors were of importance then the genetic variation should naturally be greater for the space than for the tooth-size. No positive statement can be made however, since the standard error of the differences in question are relatively great, and a difference would be significant perhaps on a larger material. It is also possible that an increase in the genetic dispersion, because of indirectly af-

fecting factors, is balanced by the occurrence of extractions on orthodontic indications which, as mentioned, should result in a decreased genetic dispersion because certain fraternal pairs with large intrageminal differences in the space-difference may have disappeared from the material.

The quotients between the various types of variability yield the following figures of the tooth-size, space and space-difference. The quotients between asymmetric and environmental variability are 0.9 and 1.6 for the sum of the tooth-breadths in the upper and lower jaw respectively, for the space 0.7 and 3.5 respectively, and for the space-difference 0.6 and 1.7 respectively. All the differences between these quotients may be conditioned by chance. The quotient between genetic and asymmetric variability for the tooth-size is 5.1 in the upper and 5.2 in the lower jaw, 2.1 and 1.8 for the space and 2.0 and 1.5 respectively for the space-difference. The difference is as mentioned, caused by the asymmetric dispersion being relatively small for the tooth-size. The quotient between genetic and environmental dispersion for the tooth-size is 4.1 and 5.2 respectively, for the space 1.6 and 6.4 respectively and for the space-differences 1.3 and 2.5 respectively. The standard error of these quotients is partly very large, and the differences may be due to random variation.

Calculations have also been made of the whole non-genetic dispersion (the sum of asymmetric and environmental variation), and of the genetic variation for the space and the space-differences from M_1 to M_1, and from I_2 to I_2, and also for the space-difference from C to M_1 (table 49). For the total space in the upper jaw the non-genetic dispersion is 2.13 ± 0.40 mm. and the genetic dispersion 3.29 ± 0.75 mm., while the corresponding values of the space-differences are 2.06 ± 0.39 mm. and 3.00 ± 0.74 mm. respectively. The space-dispersion is on account of non-heredity in the lower jaw 1.60 ± 0.32 mm., and of heredity 2.49 ± 0.59 mm. while the corresponding values of the space-difference is 1.66 ± 0.35 mm. and 1.90 ± 0.55

ble 49. **Comparison between non-genetic and genetic variability as regards space d space-difference in the dental arch in the upper and lower jaw. The variability is pressed in the standard deviation, σ, in mm.**

Character	Jaw	Age, years	Error of measurement		Non-genetic stand. dev.		Genetic stand. dev.		Heredity / Non-heredity $\frac{\sigma_2}{\sigma_1}$
			No.	$\sigma_3 \pm \varepsilon(\sigma_3)$	No.	$\sigma_1 \pm \varepsilon(\sigma_1)$	No.	$\sigma_2 \pm \varepsilon(\sigma_2)$	
Pairs without missing teeth									
rch-space $M_1 - M_1$	u	12—15			30	2.13±0.40	34	3.29±0.78	1.6±0.47
	u	12—40	40	0.41±0.05	60	1.83±0.25	44	3.48±0.64	1.9±0.44
	l	12—15			27	1.60±0.32	38	2.49±0.58	1.6±0.48
	l	12—40	39	0.42±0.05	52	1.25±0.19	46	2.58±0.46	2.1±0.48
pace-diff. $M_1 - M_1$	u	12—15			29	2.06±0.39	34	3.00±0.74	1.4±0.45
	u	12—40	40	0.31±0.03	59	1.73±0.23	44	2.96±0.57	1.8±0.40
	l	12—15			26	1.66±0.35	37	1.90±0.55	1.1±0.41
	l	12—40	40	0.55±0.06	51	1.43±0.22	45	1.89±0.42	1.4±0.36
rch-space $I_2 - I_2$	u	12—15			30	0.61±0.12	34	1.51±0.31	2.5±0.70
	u	12—40	39	0.16±0.02	60	0.84±0.11	44	1.35±0.27	1.6±0.38
	l	12—15			25	0.81±0.16	38	0.90±0.25	1.1±0.38
	l	12—40	40	0.14±0.02	53	0.65±0.09	46	0.96±0.20	1.5±0.37
pace-diff. $I_2 - I_2 \ldots$	u	12—15			30	0.68±0.14	34	0.78±0.23	1.1±0.41
	u	12—40	38	0.24±0.03	60	0.75±0.11	44	0.70±0.19	0.9±0.29
	l	12—15			28	0.66±0.15	38	0.66±0.22	1.0±0.40
	l	12—40	40	0.36±0.04	53	0.52±0.10	46	0.72±0.17	1.4±0.42
pace-diff. $C - M_1$	u	12—40	39	0.30±0.03	59	1.09±0.15	44	1.61±0.33	1.5±0.23
	l	12—40	40	0.35±0.04	50	0.97±0.15	45	0.14±0.21	0.1±0.22
Pairs with missing teeth									
rch-space $M_1 - M_1$	u	12—40	40	0.41±0.05	32	4.23±0.75	52	6.57±1.32	1.6±0.42
	l	12—40	39	0.42±0.05	36	2.99±0.51	49	5.75±1.06	1.9±0.74
pace-diff. $M_1 - M_1$	u	12—40	40	0.31±0.03	35	2.95±0.50	52	2.89±0.76	1.0±0.42
	l	12—40	40	0.55±0.06	42	2.40±0.38	51	2.74±0.64	1.1±0.55
rch-space $I_2 - I_2$	u	12—40	39	0.16±0.02	35	2.14±0.36	52	neg.	—
	l	12—40	40	0.14±0.02	42	0.62±0.10	52	1.55±0.25	2.5±0.57
pace-diff. $I_2 - I_2 \ldots$	u	12—40	38	0.24±0.03	35	2.50±0.43	52	neg.	
	l	12—40	40	0.36±0.04	42	0.55±0.11	52	1.59±0.26	2.9±0.75

mm. The values of the genetic dispersions are for the sections of the dental arch in general somewhat higher than

the values of the non-genetic dispersion, although the difference may here as well as for the whole dental arch very well be due to random variation. One exception to this is the space for the upper incisors where the genetic effect is very probably greater than that of the non-genetic (diff. = 0.90±0.33 mm.). For the space-difference in the region $C—M_1$ in the lower jaw the effect of heredity seems to be very slight. It has already been mentioned, that this should be connected with the fact that in this section the deciduous teeth are broader than the corresponding permanent teeth, which is why crowding hardly can be localized to this region unless, premature loss of deciduous teeth has occurred.

The quotient between heredity and non-heredity for the total space is 1.6 in the upper, as well as in the lower jaw, and for the space-difference 1.4 and 1.1 respectively. The standard error is rather large, however, and the values are therefore uncertain. The same is true of the quotients for sections of the dental arch, which for the incisor-space and space-difference varies between 1.0 and 2.5 respectively, and for the lateral space-difference with quotients of 1.5 in the upper and 0.1 in the lower jaw. In the latter case, the value of the lower jaw is significantly smaller than that of the upper jaw, dependent on a smaller genetic dispersion in the lower than in the upper jaw.

For the space-difference in the region of the upper incisors particularly, the dispersion within the population is clearly larger (according to calculation 1.9 times larger) than in twins (table 24, page 85). It is conceivable that this is because the dispersion within fraternal twins has been by chance too low, and thus the effect of heredity on a larger material may be proved greater than has been calculated in this material. Under all circumstances this increases the uncertainty of applying the twin-values to the population.

The dispersion appertaining to heredity as well as to non-heredity seems to be greater in pairs with missing

teeth, than in pairs without missing teeth for the space in the whole dental arch. Since the dispersion of heredity and non-heredity increases in cases with loss of teeth, the quotient between them becomes approximately the same in both materials. The greater genetic dispersion in cases with loss of teeth should mainly be a result of the fact that dissimilarities with respect to extractions are more common in fraternal than in identical pairs of twins. Here it is also conceivable that the genetic dispersion is partly conditioned by environment according to the extent fraternal twins live in more varying environment than identical as to causes leading to extractions.

As to the space-difference the corresponding differences are less marked, and may be due to random variation, which is probably connected with the fact that the space-difference in cases with loss of M_1 have been determined from P_1 (while the space in such cases was determined from M_2), which diminishes the deviations between cases of extraction and non-extraction.

As to the space and the space-difference of the upper incisors, the non-genetic dispersion is very large in pairs with losses, while the genetic dispersion is 0 due to the dispersion being smaller in fraternal than in identical twins. Here, however, the result may possibly have been caused by chance so that the differences are either too small in the fraternal, or too large in the identical twins. This question therefore, needs to be investigated further.

As to the space and the space-difference in the region of the lower front teeth, the non-genetic dispersion seems to be approximately equally as great in pairs with losses as in pairs without, which agrees with the experience that after extractions migration takes place relatively slowly in this region. On the other hand, the genetic dispersion seems to be greater in cases with losses than without (the difference $= 0.59 \pm 0.32$ mm. for the space, and 0.87 ± 0.31 mm. for the space-difference). However, this may be a random difference, even if it is also conceivable that it depends on

the fact that loss of teeth possesses, nevertheless, a certain effect which would then appear particularly in fraternal twins in whom dissimilarities as to extractions are relatively usual.

We have investigated the conditions in non-selected cases. The result obtained indicates that the environmental effect is moderate. It is obvious that in marked malocclusions the environment cannot be expected to be of any greater influence if the conditions are the same as in average occlusions i. e. if one cannot find any particular environmental factor which is of influence in malocclusions only. According to the survey of the literature it is hardly probable that any such factors exist.

Width, length and the length expressed in per cent of the width at M_1 of the dental arch (table 50). As to the width at P_1 and M_1 and the length (from M_1—M_1 to I_1), the figures of the standard deviations for non-heredity in twins without missing teeth vary from appr. 0.7 mm. (the length in the lower jaw = 0.69 ± 0.10 mm.) to appr. 1.2 mm. (the width at M_1 in the upper jaw = 1.23 ± 0.17 mm.). The figures of the genetic dispersion seem to be somewhat higher, and lie between appr. 1.3 mm. and 1.9 mm. (1.26 ± 0.24 mm. and 1.91 ± 0.34 mm. for the length in the lower and upper jaw respectively).

Between the different measurements no greater differences seem to exist. The non-genetic dispersion in the upper jaw is however possibly somewhat greater at M_1 than at P_1. The difference in the standard deviation for non-heredity is thus $+0.45 \pm 0.20$ mm.

The quotient between heredity and non-heredity varies between 1.2 (the width at M_1 in the upper jaw) and 2.8 (the width at P_1 in the upper jaw) in the younger twins, and between 1.1 (the width at M_1 in the upper jaw) and 2.2 (the length in the upper jaw) in the sum of younger and older twins. The standard errors are relatively large and the differences in the quotient values may very well be due to random variation.

Table 50 **Comparison between non-genetic and genetic variability as regards the width and the length of dental arches in mm and the length expressed in per cent of the width at M_1. The variability is expressed in the standard deviation, σ.**

Character	Jaw	Age, years	Error of measurement		Non-genetic variability		Genetic variability		Heredity / Non-heredity $\frac{\sigma_2}{\sigma_1}$
			No.	$\sigma_3 \pm \varepsilon(\sigma_3)$	No.	$\sigma_1 \pm \varepsilon(\sigma_1)$	No.	$\sigma_2 \pm \varepsilon(\sigma_2)$	
Pairs without missing teeth									
Width at P_1	u	12—15			28	0.63 ± 0.42	30	1.73 ± 0.36	2.8 ± 0.77
	u	12—40	37	0.16 ± 0.02	58	0.78 ± 0.11	40	1.65 ± 0.31	2.1 ± 0.50
Width at M_1	u	12—15			30	1.24 ± 0.23	34	1.53 ± 0.41	1.2 ± 0.40
	u	12—40	38	0.25 ± 0.03	60	1.23 ± 0.17	44	1.37 ± 0.32	1.1 ± 0.30
Length $M_1 - M_1$ to I_1	u	12—15			30	0.93 ± 0.18	34	1.95 ± 0.41	2.1 ± 0.60
	u	12—40	38	0.25 ± 0.03	60	0.87 ± 0.12	44	1.91 ± 0.34	2.2 ± 0.49
Length in per cent of width	u	12—15			30	2.21 ± 0.42	34	4.90 ± 1.02	2.2 ± 0.62
	u	12—40	39	0.57 ± 0.06	60	2.73 ± 0.36	44	4.36 ± 0.86	1.6 ± 0.38
Width at P_1	l	12—15			22	0.90 ± 0.20	35	1.49 ± 0.35	1.7 ± 0.54
	l	12—40	39	0.15 ± 0.02	47	0.89 ± 0.13	42	1.41 ± 0.29	1.6 ± 0.40
Width at M_1	l	12—15			27	0.78 ± 0.15	38	1.83 ± 0.36	2.4 ± 0.65
	l	12—40	38	0.16 ± 0.02	52	0.92 ± 0.13	45	1.66 ± 0.31	1.8 ± 0.42
Length $M_1 - M_1$ to I_1	l	12—15			27	0.78 ± 0.16	38	1.18 ± 0.28	1.5 ± 0.47
	l	12—40	37	0.19 ± 0.02	52	0.69 ± 0.10	45	1.26 ± 0.24	1.8 ± 0.44
Length in per cent of width	l	12—15			27	3.72 ± 0.73	38	5.51 ± 1.31	1.5 ± 0.46
	l	12—40	38	0.69 ± 0.08	52	3.59 ± 0.51	45	5.70 ± 1.13	1.6 ± 0.39
Pairs with missing teeth									
Width at P_1	u	12—40	37	0.16 ± 0.02	27	1.27 ± 0.25	48	1.58 ± 0.38	1.2 ± 0 39
Width at M_1	u	12—40	38	0.25 ± 0.03	19	1.17 ± 0.28	19	2.68 ± 0.73	2.3 ± 0.83
Length ($M_1 - M_1$ to I_1	u	12—40	38	0.25 ± 0.03	19	1.78 ± 0.41	15	1.12 ± 0.69	0.6 ± 0.41
Length in per cent of width	u	12—40	39	0.57 ± 0.06	19	4.28 ± 0.99	15	1.61 ± 1.55	0.4 ± 0.37
Width at P_1	l	12—40	39	0.15 ± 0.02	42	1.13 ± 0.18	44	1.22 ± 0.31	1.1 ± 0.32
Width at M_1	l	12—40	38	0.16 ± 0.02	11	(0.98 ± 0.30)	11	(2.31 ± 0.81)	(2.4 ± 1.10)
Length ($M_1 - M_1$ to I_1	l	12—40	37	0.19 ± 0.02	11	(0.70 ± 0.22)	11	(1.64 ± 0.58)	(2.3 ± 1.11)
Length in per cent of width	l	12—40	38	0.69 ± 0.08	11	(3.73 ± 1.15)	10	(9.42 ± 3.41)	(2.5 ± 1.20)

The dispersion figures in pairs with missing teeth are partly somewhat higher than in pairs without missing teeth, but the standard errors are large and the differences may very well be due to random variation.

As to length in per cent of width the standard deviation for non-heredity is appr. 2.7 per cent in the upper jaw, and 3.6 per cent in the lower, while the corresponding figures for the genetic dispersion is 4.4 and 5.7 per cent respectively. The quotient between heredity and non-heredity is appr. 1.6 in the upper as well as in the lower jaw in pairs without missing teeth, while it is appr. 0.4 in the upper and 2.5 in the lower jaw in pairs with missing teeth. The material is small and the dissimilarities may very well be conditioned by chance.

According to calculations the dispersion in the population is 1.1 to 1.4 times greater than the dispersion in fraternal twins, apart from the width at M_1 in the upper jaw where the quotient is 1.7. For this latter measurement particularly a deviation from the values calculated on twins is, therefore, conceivable as regards conditions within the population.

Inclination of the upper medial incisors. The standard deviation of non-heredity is 0.32 ± 0.04 mm. (= appr. 2°), and that of heredity 0.42 ± 0.07 mm. (= appr. 2.6°). These figures are significant in the whole material (a conjoining of pairs without and pairs with missing teeth seems justified for this character, because no differences could be proved between them neither for the non-genetic nor for the genetic dispersion). The quotient between heredity and non-heredity is appr. 1.3 in the whole material, and appr. 1.5 in pairs without missing teeth (table 51). The figures in the population should not differ greatly from the twin-figures as the difference in dispersion between the poulation and fraternal twins is small.

Height of the palatal vault. For the height of the palatal vault also, a conjoining of pairs without and pairs with missing teeth may be carried out. In whole the material

Table 51. **Comparison between non-genetic and genetic variability as regards inclination of the upper medial incisors. The variability is expressed in the standard deviation, σ, in mm[1].**

Age, years	Error of measurement		Non-genetic variability		Genetic variability		Heredity / Non-heredity
	No.	$\sigma_3 \pm \varepsilon(\sigma_3)$	No.	$\sigma_1 \pm \varepsilon(\sigma_1)$	No.	$\sigma_2 \pm \varepsilon(\sigma_2)$	$\frac{\sigma_2}{\sigma_1}$
Pairs without missing teeth							
12—15			30	0.29 ± 0.06	34	0.48 ± 0.11	1.7 ± 0.51
12—40	40	0.16 ± 0.02	60	0.30 ± 0.05	44	0.47 ± 0.10	1.5 ± 0.42
Pairs with missing teeth							
12—40	40	0.16 ± 0.02	35	0.35 ± 0.07	35	0.37 ± 0.11	1.1 ± 0.38
Pairs without and with missing teeth							
12—15			41	0.28 ± 0.06	70	0.39 ± 0.08	1.4 ± 0.41
12—40	40	0.16 ± 0.02	95	0.32 ± 0.04	96	0.42 ± 0.07	1.3 ± 0.56

[1] 1 mm = appr. 6.3°

the non-genetic standard deviation is 0.75 ±0.08 mm., and the genetic 1.40 ± 0.19 mm. The quotient between heredity and non-heredity is appr. 1.7 in pairs without missing teeth, and appr. 1.9 in whole the material (table 52). The dispersion in the population is clearly larger (according to calculation 1.6 times greater) than in twins, and it is thus apparent that heredity and/or non-heredity has a stronger influence within the population than within the pairs of twins. It is naturally possible that the effect of genetic and non-genetic factors is correspondingly greater, and that therefore the quotient between them is the same in both cases.

Sagittal occlusion. For the molar occlusion in younger twins the division of the total variability shows an asymmetric variability of appr. 1.3 mm., an environmental variability of appr. 1.1 mm. and a genetic variability of appr. 1.2 mm. In the older twins only asymmetric and environmental variability can be calculated, and they are 1.2 mm. and 0.3 mm. respectively (table 53).

The quotient between asymmetric and environmental

Table 52. **Comparison between non-genetic and genetic variability as regards the height of the palatal vault. The variability is expressed in the standard deviation, σ, in mm.**

Age, years	Error of measurement		Non-genetic variability		Genetic variability		Heredity / Non-heredity
	No.	$\sigma_3 \pm \varepsilon(\sigma_3)$	No.	$\sigma_1 \pm \varepsilon(\sigma_1)$	No.	$\sigma_2 \pm \varepsilon(\sigma_2)$	$\frac{\sigma_2}{\sigma_1}$
Pairs without missing teeth							
12—15			30	0.67 ± 0.13	34	1.04 ± 0.25	1.6 ± 0.48
12—40	37	0.19 ± 0.02	60	0.70 ± 0.10	44	1.18 ± 0.23	1.7 ± 0.41
Pairs with missing teeth							
12—40	37	0.19 ± 0.02	29	0.87 ± 0.17	48	1.57 ± 0.31	1.8 ± 0.50
Pairs without and with missing teeth							
12—15			41	0.66 ± 0.11	67	1.27 ± 0.21	1.9 ± 0.45
12—40	37	0.19 ± 0.02	89	0.75 ± 0.08	92	1.40 ± 0.19	1.9 ± 0.32

Table 53. **Comparison between error of measurement, asymmetric and environmental variability and genetic variability as regards sagittal occlusion at M_1 (cf. table 43) and different quotients for cases without missing teeth. The variability is expressed in the standard deviation, σ, in mm.**

$\sigma_{1:1}$ for asymmetric variability is calculated according to the formula $\sqrt{\sigma_D^2 - \sigma_m^2} \cdot \frac{1}{\sqrt{2}}$, where σ_D is the standard deviation of differences between left and right side in identical twins and σ_m the standard deviation of differences between double measurements on the same individual.

$\sigma_{1:2}$ for environmental variability is calculated according to the formula $\sqrt{\sigma_0^2 - \sigma_D^2} \cdot \frac{1}{\sqrt{2}}$, where σ_0 is the standard deviation of intrageminal differences of identical twin pairs.

Age, years	Error of measurement		Asymmetric variability		Environmental variability		Genetic variability		Quotients		
	No.	$\sigma_3 \pm \varepsilon(\sigma_3)$	No.	$\sigma_{1:1} \pm \varepsilon(\sigma_{1:1})$	No.	$\sigma_{1:2} \pm \varepsilon(\sigma_{1:2})$	No.	$\sigma_2 \pm \varepsilon(\sigma_2)$	$\frac{\sigma_{1:1}}{\sigma_{1:2}}$	$\frac{\sigma_2}{\sigma_{1:1}}$	$\frac{\sigma_2}{\sigma_{1:2}}$
12—15			48	1.32 ± 0.15	18	1.13 ± 0.30	26	1.22 ± 0.39	1.2 ± 0.34	0.9 ± 0.31	1.1 ± 0.45
16—40			25	1.23 ± 0.19	18.5	0.26 ± 0.29	6	·	4.7 ± 5.31	—	—
12—40	35	0.29 ± 0.03	73	1.28 ± 0.12	36.5	0.54 ± 0.20	32	1.45 ± 0.31	2.4 ± 0.91	1.1 ± 0.26	2.7 ± 1.15

variability in the younger twins is appr. 1.2 and in the older appr. 4.7. The difference between these values may very well be conditioned by chance. The quotient between genetic and asymmetric variation is appr. 0.9, and between genetic and environmental variation appr. 1.1 in younger twins.

The comparison between the dispersion of heredity and the dispersion of the whole non-heredity is apparent from table 54. The standard deviation of non-heredity in younger twins is appr. 1.9 mm. on the left, and 1.2 mm. on the right side, while the standard deviation of heredity is appr. 1.0 mm. and 1.5 mm. respectively. The dispersion value of non-heredity for the mean value between the left and the right side is appr. 1.4 mm. and for heredity appr. 1.2 mm. The quotient between heredity and non-heredity is appr. 0.5 for the left side, 1.3 for the right and 0.8 for the mean value.

No significant differences could be proved between pairs without and pairs with missing teeth. The quotient between genetic and non-genetic variation in the latter case is appr. 0.5, 0.4 and 0.5.

The non-genetic standard deviation for the *sagittal overbite* is appr. 0.6 mm. in younger twins while the genetic standard deviation is appr. 1.7 mm. The quotient between heredity and non-heredity is appr. 3.0. No difference between pairs without, and pairs with missing teeth could be proved neither with respect to the non-genetic nor the genetic dispersion. The quotient between heredity and non-heredity for pairs without missing teeth is appr. 1.2.

The dispersion within the population is approximately the same size as in fraternal twins for the molar occlusion as well as for the sagittal overbite (table 24, page 85). Hence it is not probable that the conditions within the population differ appreciably from those values obtained from the twin-material.

Vertical overbite. In the sum of younger and older pairs without missing teeth, the non-genetic standard deviation

Table 54. **Comparison between non-genetic and genetic variability as regards the occlusion between the upper and lower jaw. The variability is expressed in the standard deviation, σ, in mm.**

Character	Age, years	Error of measurement		Non-genetic variability		Genetic variability		Heredity / Non-heredity
		No.	$\sigma_3 \pm \varepsilon(\sigma_3)$	No.	$\sigma_1 \pm \varepsilon(\sigma_1)$	No.	$\sigma_2 \pm \varepsilon(\sigma_2)$	$\frac{\sigma_2}{\sigma_1}$
Pairs without missing teeth								
Sag. occl. at M_1 (left side)	12—15			19	1.92 ± 0.45	26	0.96 ± 0.62	0.5 ± 0.34
	12—40	36	0.36 ± 0.04	38	1.62 ± 0.27	32	1.37 ± 0.47	0.9 ± 0.32
Sag. occl. at M_1 (right side)	12—15			17	1.15 ± 0.29	26	1.47 ± 0.47	1.3 ± 0.52
	12—40	35	0.34 ± 0.04	35	1.16 ± 0.21	30	1.54 ± 0.41	1.3 ± 0.43
Sag. occl. at M_1 (average)	12—15			19	1.43 ± 0.34	26	1.15 ± 0.50	0.8 ± 0.55
	12—40	35	0.29 ± 0.03	36	1.29 ± 0.22	32	1.38 ± 0.41	1.1 ± 0 89
Sagittal overbite	12—15			24	0.57 ± 0.13	27	1.73 ± 0.38	3.0 ± 0.96
	12—40	40	0.27 ± 0.03	44	0.93 ± 0.15	34	1.79 ± 0.38	1.9 ± 0.51
Vertical overbite	12—15			22	0.72 ± 0.16	25	0.90 ± 0.28	1.3 ± 0.48
	12—40	37	0.22 ± 0.03	42	0.62 ± 0.10	31	0.95 ± 0.23	1.6 ± 0.45
Diff. between u. and l. jaw in arch width at P_1	12—15			19	0.62 ± 0.15	24	1.69 ± 0.40	2.7 ± 0.92
	12—40	37	0.22 ± 0.03	39	0.67 ± 0.12	30	1.66 ± 0.35	2.5 ± 0.69
Diff. between u. and l. jaw in arch width at M_1	12—15			24	1.26 ± 0.27	27	1.00 ± 0.41	0.8 ± 0.37
	12 - 40	36	0.32 ± 0.04	44	1.00 ± 0.16	33	1.36 ± 0.34	1.4 ± 0.40
Pairs with missing teeth								
Sag. occl. at M_1 (left side)	12—40	36	0.36 ± 0.04	16	2.02 ± 0.51	21	1.03 ± 0.72	0.5 ± 0.38
Sag. occl. at M_1 (right side)	12—40	35	0.34 ± 0.04	18	2.06 ± 0.49	19	0.87 ± 0.71	0.4 ± 0.36
Sag. occl. at M_1 (average)	12—40	35	0.29 ± 0.03	20	1.68 ± 0.39	29	0.80 ± 0.52	0.5 ± 0.33
Sagittal overbite	12—40	40	0.27 ± 0.03	50	0.88 ± 0.13	61	1.06 ± 0.22	1.2 ± 0.31
Vertical overbite	12 - 40	37	0.22 ± 0.03	48	0.81 ± 0.12	58	0.78 ± 0.19	1.0 ± 0.27
Diff. between u. and l. jaw in arch width at P_1	12—40	37	0.22 ± 0.03	42	1.35 ± 0.21	50	0.84 ± 0.31	0.6 ± 0.25
Diff. between u. and l. jaw in arch width at M_1	12—40	36	0.32 ± 0.04	17	1.17 ± 0.30	18	1 63 ± 0 56	1.4 ± 0.60

is appr. 0.6 mm., and the genetic appr. 0.9 -1.0 mm. In pairs with missing teeth the corresponding figures are appr. 0.8 and 0.8 mm. respectively. The quotient between heredity and non-heredity in pairs without missing teeth is

appr. 1.3 and in pairs with missing teeth appr. 1.0. The dispersion in the population is probably greater (according to this material appr. 1.4 times greater) than in twins which is why the population should show somewhat higher dispersion values than the above mentioned, and maybe also somewhat deviating quotient values.

Difference in the arch-width between the upper and lower jaw. In pairs without missing teeth the non-genetic standard deviation of the width-difference at P_1 is appr. 0.7 mm. while the genetic is appr. 1.7 mm. For the width-difference at M_1 the corresponding figures are appr. 1.0 mm. and 1.4 mm. The quotient between heredity and non-heredity is at P_1 appr. 2.5 and at M_1 1.4, in which the difference may very well be caused by chance. In pairs with missing teeth the influence of non-heredity on the width-difference at P_1 seems to be greater than in pairs with missing teeth (the difference in the standard deviation $= 0.68 \pm 0.24$ mm.). This may be connected with the migration of P_1 in cases with missing teeth e. g. in the form of distal migration where M_1 has been lost, so the distance may be increased between P_1 on the left and right side. The quotient between heredity and non-heredity in pairs with missing teeths is appr. 0.6 for the width-difference at P_1, and appr. 1.4 for the width-difference at M_1. The quotient-value at P_1 is probably smaller than the corresponding value in pairs without missing teeth (the difference $= 1.9 \pm 0.7$).

In the population the dispersion for the width-difference is probably somewhat greater (according to calculations 1.2 times greater at P_1 and 1.4 times greater at M_1) than in fraternal twins. Since the differences seem to be small, the twin-values are probably, on the whole, significant for the population also.

SUMMARY

A survey of the literature shows that the etiology of malocclusion of the teeth is a question which is far from being fully explained. Some few authors have endeavoured by means of twin-investigations to elucidate to which extent genetic and environmental factors cause malocclusions. The method applied by these authors is imperfect in several respects which is why their results cannot be regarded as definitive.

The present investigation is based upon measurements taken from 100 identical and 102 fraternal twin-pairs of the same sex, of which 9 pairs were aged 8—12 years, 112 pairs 12—15 years and 81 pairs 16—40 years. A calculation of the error of measurement shows that it does not exceed 1.5 per cent. The representativeness of the material is satisfactory, though its variability in several respects is somewhat less than in the total population, which from a theoretical point of view is to be exspected. The results obtained are as follows:

1. Regarding the tooth-breadths and the space of the teeth, the investigation comprised: a) the variability between the left and right side in the individual, b) the variability between identical twins, c) the variability between fraternal twins. When treating the material, the formulae advanced by *Dahlberg* (see chapter III) have been applied.

a. It appears that for the medial upper incisor the standard deviation is 0.19 mm. for the dissimilarities between left and right side; 0.22 mm. for the dissimilarities between identical twins, and 0.52 mm. for the dissimilarities between fraternal twins. Corresponding figures for the lateral incisor are 0.37 mm., 0.38 mm. and 0.58 mm., and

for the canine 0.18 mm., 0.21 mm. and 0.39 mm. The figures for the other individual teeth vary between 0.14 mm. and 0.34 mm., for the identical twins, and between 0.32 mm. and 0.64 mm. for the fraternal twins.

b. The variability for the sum of the tooth-breadths from the first molar on the left side to the first molar on the right side is 1.3 mm. in identical, and 4.7 mm. in fraternal twins in the upper jaw, while the corresponding figures in the lower jaw are 1.1 mm. and 4.2 mm.

c. The standard deviation for the space from the medial incisor to the first molar in the upper jaw is 1.2 mm. between the left and right side, and 1.9 mm. between identical twins. Corresponding figures in the lower jaw are 1.2 mm. and 1.2 mm. respectively. The comparison between identical and fraternal twins was made for the total space from the first molar on the left side to the first molar on the right side. The standard deviation for the space in the upper jaw is 3.1 mm. between identical twins, and 5.6 mm. between fraternal twins, while corresponding figures in the lower jaw are 2.3 mm. and 4.3 mm. respectively.

d. As regards the space-difference (i. e. the difference between the space occupied by the teeth and the sum of the tooth-breadths) within the half of the dental arch, the variability in the upper jaw is 1.1 mm. between the left and right side, and 1.9 mm. between identical twins; the corresponding figures in the lower jaw are 1.2 mm. and 1.4 mm. The variability for the total space-difference in the upper jaw is in identical twins 2.9 mm., and in fraternal twins 5.2 mm., and 2.5 mm. and 3.7 mm. respectively in the lower jaw.

2. Measurements have also been made as to the size and shape of the jaws, namely

a. in the first instance, the arch-width between the first premolars and between the first molars. In the upper and lower jaw the variability at the first premolars is 1.1 mm. and 1.3 mm. respectively in the identical, and 2.6 mm. and 2.4 mm. in the fraternal twins, while the figures at

the first molars are 1.8 mm. and 1.3 mm. in the identical, and 2.6 mm. and 2.7 mm. in the fraternal twins.

b. For the arch-length from the first molars to the medial incisors, the variability in the upper and lower jaw is 1.3 mm. and 1.0 mm. in the identical twins, and 3.0 mm. and 2.0 mm. in the fraternal twins.

c. For the length expressed in per cent of the width at the first molars the figures are 3.9 per cent and 5.2 per cent in the identical, and 7.3 per cent and 9.6 per cent in the fraternal twins.

d. The inclination of the upper medial incisors towards the occlusal plane shows a variability of 3.0° in the identical, and 5.2° in the fraternal twins.

e. As regards the height of the palatal vault from the occlusal plane at the first molars, the standard deviation in the identical twins is 1.0 mm., and in the fraternal 2.0 mm.

3. The occlusion between the jaws was investigated in the sagittal, vertical and transversal plane.

a. For the mesio-distal occlusion at the first molars, the variability between the left and right side is 1.9 mm., between identical twins 2.0 mm., and between fraternal twins 2.9 mm.

b. The sagittal overbite shows a variability of 0.9 mm. in the identical, and 2.6 mm. in the fraternal twins. The corresponding figures for the vertical overbite are 0.9 mm. and 1.6 mm. respectively.

c. The difference between the jaws in the arch-width at the first premolars and first molars respectively, shows a standard deviation of 1.0 mm. and 1.5 mm. in the identical, and 2.6 mm. and 2.4 mm. in the fraternal twins.

4. Based on the figures stated above, the dissimilarities between the individuals can be attributed to groups of factors, namely: a) to factors causing differences between the left and right side, which should mainly be based upon internal factors randomly distributed and active during the development of the fetus, but which can also be at-

tributed to environmental and genetic factors with unilateral effect, b) environmental factors with symmetric effect such as varying nutrition, function etc., and c) genetic factors with symmetric effect. The division is according to that stated by *Dahlberg* in a paper, which has not as yet been published. One can utilize the material to make a theoretical calculation of the standard deviations that these groups of factors would cause if they acted separately. It is, however, impossible to calculate the asymmetric variability for other than bilateral characters. In cases where it is impossible to calculate this variability, the environmental variability will also include the random variability during the development of the fetus, and then it is appropriate to distinguish between genetic and non-genetic variability. The division of the variability gave the following results:

a. For the breadth of the medial incisor in the upper jaw the asymmetric variability is 0.12 mm., the environmental variability 0.07 mm,. and the genetic variability 0.34 mm. The corresponding figures for the lateral incisor are 0.25 mm., 0.05 mm. and 0.35 mm., and for the canine 0.12 mm., 0.06 mm. and 0.25 mm. For the other teeth the non-genetic variability varies between 0.08 mm. and 0.18 mm., and the genetic variability between 0.20 mm. and 0.38 mm.

b. For the sum of the tooth-breadths from the first incisor to the first molar, the asymmetric variability in the upper jaw is 0.3 mm., the environmental variability 0.4 mm., and the genetic variability 1.6 mm., while in the lower jaw the corresponding figures are 0.3 mm., 0.2 mm. and 1.5 mm.

c. For the space from the medial incisor to the first molar the corresponding figures are in the upper jaw 0.8 mm., 1.1 mm., and 1.7 mm. and in the lower jaw 0.8 mm., 0.2 mm. and 1.4 mm. For the space in the whole jaw the non-genetic variability in the upper jaw is 2.1 mm., and

the genetic variability 3.3 mm., while in the lower jaw the corresponding figures are 1.6 mm. and 2.5 mm.

d. The asymmetric variability in the upper jaw for the space-difference from the medial incisor to the first molar is 0.7 mm., while the environmental variability is 1.1 mm., and the genetic variability 1.4 mm. For the lower jaw the figures are 0.8 mm., 0.5 mm. and 1.1 mm. The non-genetic variability for the whole dental arch is 2.1 mm. in the upper, and 1.7 mm. in the lower jaw, while the genetic variability is 3.0 mm. and 1.9 mm. respectively.

e. For the arch-width at the first premolar and first molar the non-genetic variability in the upper jaw is 0.8 mm. and 1.2 mm., and in the lower jaw 0.9 mm. and 0.9 mm. Corresponding figures for the genetic variability is 1.7 mm. and 1.4 mm. in the upper jaw, and 1.4 mm. and 1.7 mm. in the lower jaw.

f. The arch-length shows a non-genetic variability of 0.9 mm. in the upper, and 0.7 mm. in the lower jaw, while the figures for the genetic variability are 1.9 mm. and 1.3 mm.

g. The length in per cent of the width at the first molars shows a non-genetic variability of 2.7 per cent in the upper, and 3.6 per cent in the lower jaw, while the genetic variability is 4.4 per cent and 5.7 per cent respectively.

h. The non-genetic and genetic standard deviation for the inclination of the upper medial incisors is 1.9° and 3.0° respectively.

i. The height of the palatal vault shows a non-genetic variability of 0.7 mm., and a genetic of 1.2 mm.

j. For the molar occlusion the asymmetric variability is 1.3 mm., the environmental variability 0.5 mm. and the genetic variability 1.5 mm.

k. The sagittal overbite shows a non-genetic variability of 0.6 mm., and a genetic of 1.7 mm. For the vertical overbite the corresponding figures are 0.6 mm. and 1.0 mm.

l. The difference in the arch-width between the jaws at the first premolar and at the first molar shows a non-

genetic dispersion of 0.7 mm. and 1.0 mm. respectively, and a genetic dispersion of 1.7 mm. and 1.4 mm. respectively.

As regards the tooth-breadths the above stated specifications refer to the whole material, while for the occlusion, pairs over 12 years of age only have been used for the calculation. For the space and the sagittal overbite the figures refer to twin-pairs aged 12—15 years, as there seems to be for these characters a displacement towards smaller and larger differences respectively between the twins after this age, and also because the age distribution in the material is not equal within the identical and fraternal twins. In order not to burden the summary, figures are not given for twin-pairs in whom one or both twins have lost certain teeth. Specifications as regards this are found in the respective chapters.

In order to illustrate further the figures obtained, a graphic representation of these is given in figs. 26—29. As regards the tooth-breadth the coefficients of variation have been used here, by means of which a comparison between the different teeth is facilitated. On the whole, it appears that genetic factors play an important part, in any case equally as important as environmental factors. It is surprising that the asymmetric variability, which should mainly be conditioned by internal factors, is so great, often greater than the variability on account of the environmental factors with symmetric effect during later life. Finally, it must be emphasized that the investigation refers to an average-material with relatively moderate deviations from what is commonly characterized as a normal occlusion. Since environmental factors are of limited importance, it is to be expected, when extreme malocclusions are concerned, that heredity will be the most important factor provided that it has been impossible to prove especially environmental factors in the form of trauma or similar.

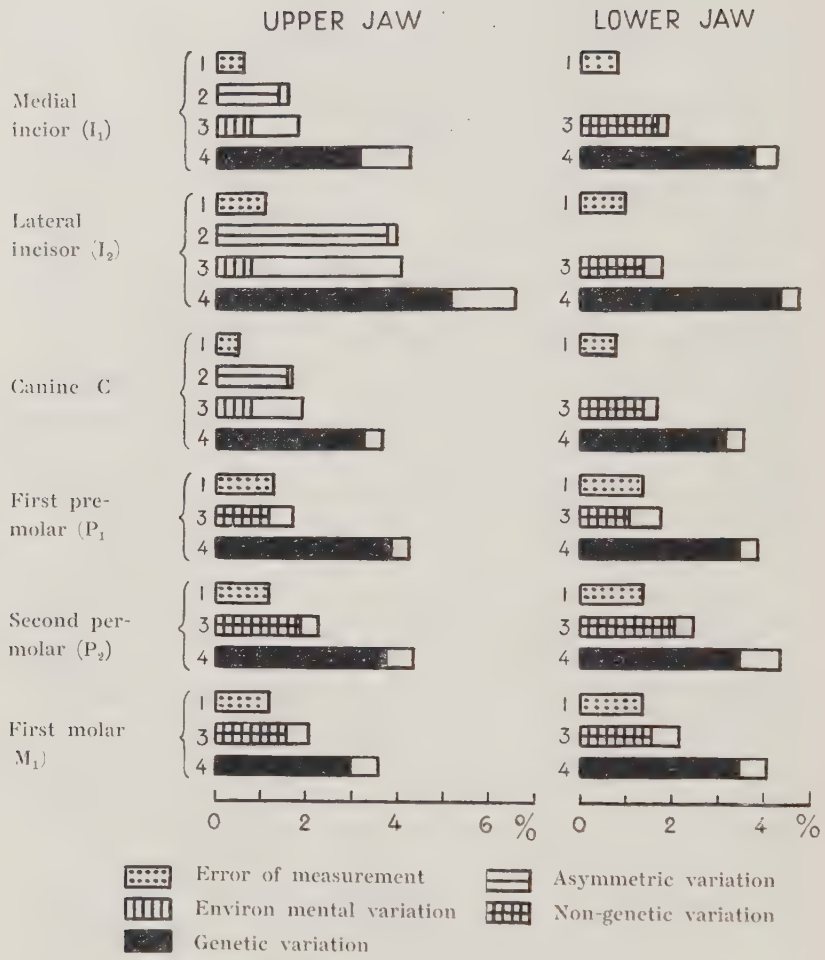

Fig. 26. *Tooth-breadths.* Variability for differences between: (1) *double measurements on the same individual,* (2) *left and right side,* (3) *identical co-twins* and (4) *fraternal co-twins.* Within the whole staples there are shorter staples for *asymmetric* (left-right variation minus error of measurement), *environmental* (variation in identical twins minus left-right variation), *non-genetic* (variation in identical twins minus error of measurement) and *genetic* variations (variation in fraternal twins minus variation in identical twins). The variations are expressed as standard deviations of a single side or a single individual.

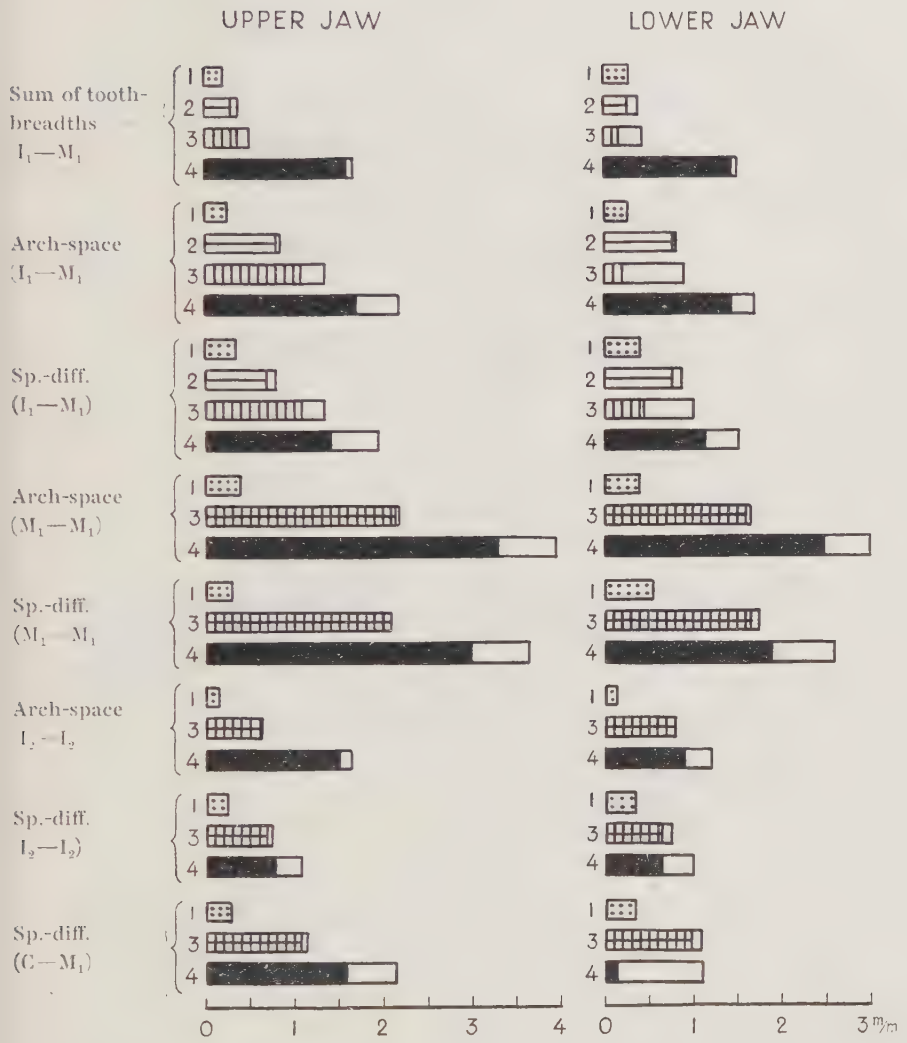

Fig 27. Variability for *sum of tooth-breadths* and *space in dental arches* (cf. fig. 26).

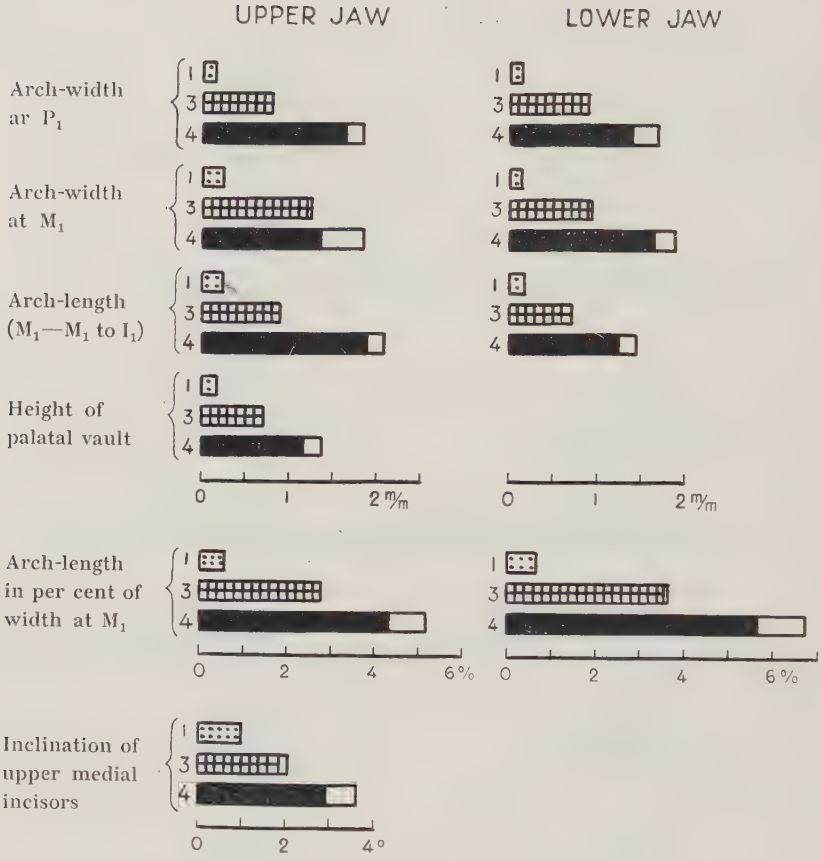

Fig. 28. Variability for *width, length* and *length in percent of width of dental arches, height of palatal vault* and *inclination of upper medial incisors.* (cf. fig. 26).

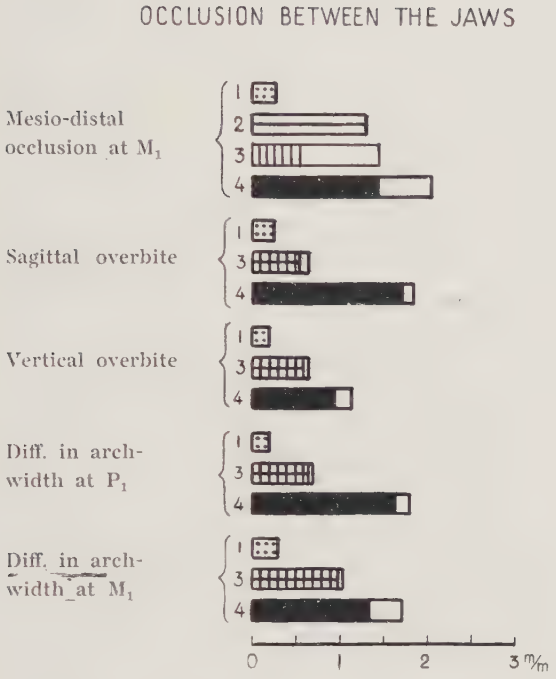

Fig. 29. Variability for *occlusion* between the jaws in the *sagittal vertical* and *transversal plane* (cf. fig. 26).

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A.-B. Fahlcrantz' Boktryckeri
Stockholm
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